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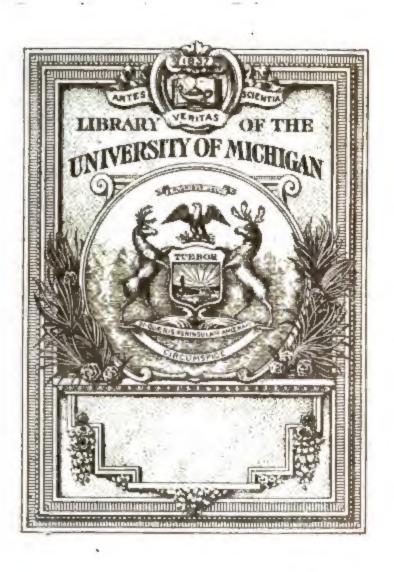
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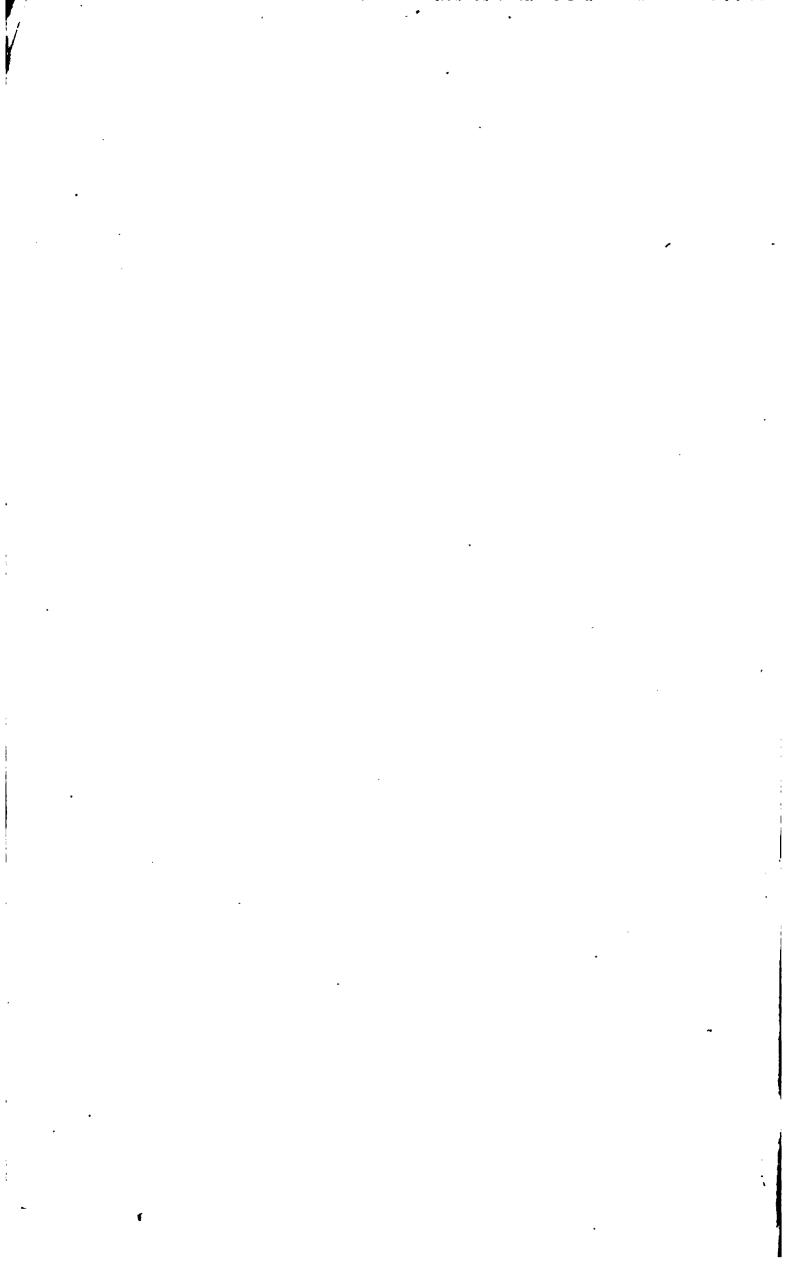




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THE METALLURGISTS AND CHEMISTS' HANDBOOK

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THE METALLURGISTS AND CHEMISTS' HANDBOOK

A REFERENCE BOOK OF TABLES AND DATA FOR THE STUDENT AND METALLURGIST

COMPLED BY

DONALD M. LIDDELL

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SECOND EDITION
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PREFACE TO SECOND EDITION

In preparing the second edition of the "Metallurgists and Chemists' Handbook" there has been no change from the plan originally adopted, and the additions, in the main, have been largely those bearing on war activities, such as additional information on alloys and toxic gases. Unfortunately much that I should like to print on these subjects is at present forbidden ground. A short chapter has also been added on "Organic Chemistry," and an attempt made to present the new concepts concerning the constitution of matter.

Thanks are due to the many friends who have pointed out the defects of the first edition. Among these I feel most indebted to Dr. Colin G. Fink for notes on the constants of tungsten; B. A. Robinson for a careful review of practically the entire book; and Dr. Robert B. Sosman for notes on the

carbonates and silicates.

DONALD M. LIDDELL.

Washington, D. C., April 15, 1918.

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PREFACE TO FIRST EDITION

This book is but little more than a collection of tables—those which my own experience and the requests from the readers of the Engineering and Mining Journal have led me to believe were most necessary to the chemist and metallurgist. There is no lengthy discussion of processes or apparatus. The field of descriptive metallurgy is at present too crowded by the monumental works of Schnabel, Hofman, Roberts-Austen and others, to admit of further competition. Certain sections will probably be criticized for their brevity, but these treat of those processes where there are no tables of constants, and the matter must either be descriptive or else non-existent.

In the preparation of these tables I have been constantly struck by the divergent values given by different authorities for the same constants. While space has usually prevented my giving the names of the experimenters and the dates of their work, I have attempted to exercise some discrimination in the choice between published values, taking into consideration the experimenter where known, and so far as available, the methods used, and, if I had not the original source, the general character

of the book in which his work was transcribed.

Yet, on the theory of probability only, the choice cannot always have been a happy one. Again, apart from any reliability of the figures as I have found or chosen them, several years of sad experience have demonstrated the fallibility of compositors and proofreaders. So for all the unknown errors of fact, of judgment and of type contained herein, I herewith tender apology. And I shall therefore take it as a favor to be advised of any errors which the reader may detect, at the same

time asking his indulgence concerning them.

Thanks are due the many publishers who have so kindly allowed copying from their publications—who they are can be seen from the footnote credits through the book. I must also thank the friends who have aided me in its preparation: Dr. Edward Weston, of Elizabeth, N. J., and W. R. Ingalls, H. A. Megraw and Percy E. Barbour, of the Engineering and Mining Journal. Mr. Megraw contributed nearly all the data on ore dressing and cyanidation and Mr. Barbour, besides giving some valuable data, checked the page proof from beginning to end. He is doubtless the only man beside the author who will ever read the entire book. And more than all is appreciation due for the many hours of painstaking work by my wife in compiling and checking the various tables, and in reading the proofs.

DONALD M. LIDDELL.

ELIZABETH, N. J. February 11, 1916.

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CONTENTS

	1 A	J L
PREFACE		v
SEC. I	. Mathematics	1
SEC. II	. Price and Production Statistics 5	3
SEC. III	. Physical Constants	75
SEC. IV	CHEMICAL DATA	39
SEC. V	. Sampling, Assaying and Analysis 3	18
SEC. VI	ORE DRESSING	55
SEC. VII	CYANIDATION	19
SEC. VIII	FUELS AND REFRACTORIES	29
SEC. IX	. MECHANICAL ENGINEERING AND CONSTRUC-	
	TION	56
SEC. X	GENERAL METALLURGY) 1
SEC. X	I. Organic Chemistry 62	25
SEC. XII	[. First Aid	32
INDEX .		Į1

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METALLURGISTS AND CHEMISTS' HANDBOOK

SECTION I

MATHEMATICS

SYMBOLS

The abbreviations given below will be standard in this book. t has been attempted to make them conform to those recommended by the International Electrotechnical Commission, and the current practice of the best edited chemical, physical, and mathematical publications.

- A ampere; work (the latter also represented by W)
- a acceleration
- B magnetic flux density
- B, b breadth
- C coulombs; electric capacity; Centigrade temperature
- D electrostatic flux density; depth
- d differential
- coefficient of adiabatic expansion, 1.406 approx.
- Δ heat; increment
 - d partial differential
 - E, e electromotive force; lumens per cm.2, foot candles
 - e base of Napierian logarithms = 2.718281828459
 - dielectric constant
 - F factor of safety; farad1
 - f frequency; force; coefficient of friction
 - 7 conductance
 - g acceleration due to gravity = 981 cm. per sec.
 - H magnetic field; henry1
- H, h height; head
 - η efficiency
 - I, i current; international candle
 - i imaginary square root of -1; in older works, amperes J intensity of magnetization; mechanical equivalent of heat, the joule¹
 - k susceptibility
 - L self inductance; lumen-second or-hour
 - l length2
- M mutual inductance

1 Recommended by the International Electrotechnical Commission for se after numerical values.

In dimensional equations, use L, M, T, for length, mass and time.

```
mass<sup>2</sup>
m
     permeability; coefficient of friction
 μ
     number of turns in unit of time
n
     angular velocity, \frac{2\pi}{T}
     power; pressure
     pressure
p
     ratio of circumference to diameter = 3.1415926535897
     quantity of electricity
     resistance; gas constant
     radius
     resistivity
     reluctance
Σ
     summation
     absolute temperature; thickness; period
     temperature, time, thickness
0, 3 temperature centigrade
     temperature absolute
  , v velocity, volt1
     reactance
W
     weight; energy; watt1
w
     weight
     phase displacement
```

Mathematical Symbols

magnetic flux

impedance

Ф **Z**

+	plus, positive	Z	angle
-	minus, negative plus or minus equals or equal to equivalent to multiplied by divided by greater than less than		parallelogram
±	plus or minus		square
==	equals or equal to	0	circle
≈	equivalent to	Ŀ	right angle
×	multiplied by	1	perpendicular to degree, hour
÷	divided by	0	degree, hour
>	greater than	,	minute, foot
<	less than	"	second, inch
	varies as	$\sqrt[n]{a}$	"n"th root
([{-]]), symbols denoting	a^n	"n"th power
	numbers enclosed are con-	Σ	summation
	sidered as one expression	مہ	cycle
Δ	triangle	Δ	increment
π	ratio of circumference	S	integral
	to diameter	6	partial differential
log	logarithm		identical
logn	log to base "n"	÷	approaches
a:b:	$c: c: d, \frac{a}{b} = \frac{c}{d}, a \text{ is to } b \text{ as}$	œ	infinity

¹ Recommended by the International Electrotechnical Commission for use after numerical values.

² In dimensional equations, use L, M, T, for length, mass and time.

Trigonometric Abbreviations

sin	sine	tan	tangent
COS	cosine	\mathbf{cot}	cotangent
sec	secant	versin	versed sine
CSC	cosecant	covers	coversed sine
sin-	$^{1}\theta$ angle whose sine is θ	$\sin \theta^{-1}$	$\frac{1}{\sin \theta}$

The Greek Alphabet

$\mathbf{A}, \boldsymbol{\alpha}$	alpha	I,L	iota .	$\mathbf{P}, \boldsymbol{\rho}$	rho
$\mathbf{B},\boldsymbol{\beta}$	beta	K,ĸ	kappa	Σ, s, σ	sigma
Γ,γ	gamma		lambda	T, τ	tau
Δ, δ	delta	M,μ	mu	T,v	upsilon
E, e	epsilon	N, v	nu	Φ, ϕ	phi
	zeta	Ξ,ξ		X,χ	
$\mathbf{H}, \boldsymbol{\eta}$		0,0	omicron	Ψ,ψ	psi
$\Theta, \theta, \vartheta$	theta	Π,π	pi	Ω,ω	omega

Mathematical Constants

$$e = 2.718281828459045$$

$$\pi = \frac{355}{113} \text{ (approx.)}.$$

$$\frac{\pi}{\pi} = 3.14159265358979$$

$$\sqrt{\pi} = 1.772$$

$$\pi^{2} = 9.8696$$

$$\frac{1}{\pi} = 0.5642$$

$$\sqrt{\frac{2}{3}} = 1.4142136$$

$$\sqrt{\frac{3}{5}} = 0.7937002$$

$$\sqrt{\frac{3}{5}} = 1.7320508$$

$$\log_{\bullet} 10 = 0.434294$$

$$e = \frac{299}{110} \text{ (approx.)}.$$

$$\log_{\bullet} \pi = 0.4971499$$

$$\log_{\bullet} x = 2.302585 \log_{10} x$$

$$\frac{1}{\pi_{2}} = 0.10132$$

$$\sqrt{\frac{3}{5}} = 1.4422509$$

$$\sqrt{\frac{3}{5}} = 2.2360680$$

$$\sqrt{\frac{3}{5}} = 1.709621$$

Temperature Reduction

The Fahrenheit scale is based on 212° as the boiling point of water at normal pressure, 32° as the freezing point. Its zero was formerly supposed to be the lowest temperature attainable artificially.

The Centigrade (Celsius) scale assumes the freezing point of water as being 0°, the boiling point under normal pressure as 100°.

The Reaumur scale assumes the freezing point of water as 0°, the boiling point of water as 80°.

$$\frac{8}{10}$$
 C.° = R.°; $\frac{10}{8}$ R.° = C.°
 $\frac{5}{9}$ (F.° - 32) = C.°; $\frac{9}{5}$ C.° + 32 = F.°
 $\frac{4}{9}$ (F.° - 32) = R.°; $\frac{9}{4}$ R.° + 32 = F.°

Units of Heat

The British Thermal Unit (B.T.U.) is the quantity of heat required to raise the temperature of 1 lb. of water 1°F., at one near its maximum density (39.1°F.).

The calorie (cal.) is the quantity of heat necessary to raise the temperature of 1 gram of water from 10°C. to 11°C. (sometimes also defined as "from 4°C. to 5°C.," less commonly still, from "0°C. to 1°C."

The kilogram-calorie (Cal.) is 1000 times the above.

The pound-calorie is the quantity of heat necessary to raise the temperature of 1 lb. of water 1°C. (usually from 4°C. to 5°C.).

1.0 Cal. = 3.968 B.T.U. = 2.2046 lb.-cal. 1.0 B.T.U. = 0.252 Cal. = 778 ft.-lb. 1 lb.-Cal. = ½ B.T.U. = 0.4536 Cal.

Latent heat of a substance is the number of calories required to be absorbed to change 1 gram of the substance from a solid to a liquid or a liquid to a gas, without change of temperature. An equal quantity is given out when the reverse change takes place.

Specific heat of a substance is the ratio of the quantities of heat necessary to raise the temperature of equal masses of the substance and of water from the same to the same

temperatures.

The equivalent points on the different scales are

 $0.0^{\circ} C = 0.0^{\circ} R.$ - $40.0^{\circ} C = -40.0^{\circ} F.$ - $25.6^{\circ} R = -25.6^{\circ} F.$

Scale of Temperatures by Color of Iron¹

Dark red—hardly visible	970°F.	Orange	2000°F.
Dull red	1300°F.	Yellow	2150°F.
Cherry—dark	1450°F.	White heat	2350°F.
Cherry—red	1650°F.	White welding	2600°F.
Cherry—light	1800°F.	White—dazzling	2800°F.

Standard Thermometric Points²

Ice melts	0.0°C.	Zinc solidifies	419.4°C.
Water boils	100.0°C.	Sulphur boils	444.7°C.
Aniline boils	184.1°C.	Antimony solidifies	630.7°C.
Naphthalene boils	218.0°C.	Sodium chloride	
Tin solidifies	231.9°C.	solidifies	801.0°C.
	306.0°C.	Silver solidifies	960.5°C.
Lead solidifies	327.4°C.	Copper solidifies	1083.0°C.

Weights and Measures

LINEAR MEASURE—ENGLISH

12 in. = 1 ft. 3 ft. = 1 yd.

 $5\frac{1}{2}$ yd. or $16\frac{1}{2}$ ft. = 1 rod or perch.

320 rods, 1760 yd., 5280 ft. = 1 mile.

Also a number of miscellaneous units, some of which are obsolete, or obsolescent, others are used by certain trades only.

¹ For tables of melting points, see pp. 140, 216, 254 and 452. For Segercone data see p. 450.

According to the National Physical Laboratory.

```
= \frac{1}{2} in.
= \frac{1}{2} in.
   A point
   A line
   A barleycorn
                                = \frac{1}{3} in.
   A palm
                                = 3 \text{ in.}
   A hand
                                = 4 in.
                                = 9 in.
   A span
   A cubit
                                = 18 \text{ in.}
                                = 30 \text{ in.}
   A military pace
   A link
                                = 1100 chain
   A knot (nautical mile) = 6086 ft.
                                = 6 ft. (United States)
   A fathom
   A fathom
                                = 6.08 ft. (British)
   1 ell (English)
                                = 45 in.
   1 ell (Dutch)
                                = 1.094 \text{ yd}.
   1 bolt
                                = 40 \text{ yd}.
                                = 4 \text{ rods } (66 \text{ ft.}) = 20.117 \text{ meters}
   A chain
                                = 1/8 mile
   A furlong
   A league
                                = 3 \text{ knots}
   A cable length
                                = 120 fathoms (United States)
   A cable length
                                = 608 ft. (British)
An International Geographical mile = ½5° at equator = 24,350.3 ft.
A British nautical mile
                                             = 6.080.4 \, \text{ft.}
```

Linear Measure—French¹

10 millimeters = 1 centimeter
10 centimeters = 1 decimeter
10 decimeters = 1 meter
10 meters = 1 dekameter
10 dekameters = 1 hektometer
10 hektometers = 1 kilometer
10 kilometers = 1 myriameter.

A micron is 1_{000} mm.; a millimicron = 1_{000} micron; 1 ångström unit = 1_{000} millimicron

Conversion Table, Linear Measure

The old French measures and their equivalents are:

1 toise = 1.9490366 m. 1 pied = 0.3248394 m. 1 pouce = 2.706995 cm. 1 ligne = 0.225583 cm.

1 toise = 6 pieds = 72 pouces = 864 lignes

The decimeter, dekameter, hektometer and myriameter are seldom used as compared with the other measures. When the metric system was devised the meter was supposed to be one ten-millionth part of the quadrant of the earth's surface. However, owing to inaccuracies of measurement, this is only approximately true, and the meter must be defined as the length of a standard bar of platinum kept in Paris, when measured at a temperature of zero degrees centigrade.

Square Measure—English

```
144 sq. in.
                                          = 1 \text{ sq. ft.}
                                          = 1 \text{ sq. yd.}
                        9 sq. ft.
                  30.25 sq. yd. \
                                          = 1 \text{ sq. rod}
                 272.25 sq. ft. \int
                     160 sq. rd.
                       10 sq. ch.
                                          = 1 acre
                        4 roods
                  43,560 sq. ft.
                     640 acres
                                          = 1 sq. mi.
A square of flooring or roofing = 100 \text{ sq. ft.}
A section of land
                                       = 1 \text{ mi. sq.}
A township
                                       = 36 \text{ sq. mi.}
A board foot
                                       = 1 \text{ ft. square} \times 1 \text{ in. thick}
```

Square Measure—French

```
100 sq. mm. = 1 sq. cm.

100 sq. cm. = 1 sq. dm.

100 sq. dm. = 1 sq. m. (centar)

100 sq. m. = 1 sq. dekameter or ar

100 sq. dekameters = 1 sq. hektometer (hektar)

100 sq. hektometers = 1 sq. kilometer
```

Conversion Table, Square Measure

```
1 centar (1 sq. m.) = 1550 sq. in. = 10.764 sq. ft.

1 ar = 119.6 sq. yd.

1 hectar = 2.47104 acres. 1 acre = 0.40469 hektar

1 sq. cm. = 1.5500 sq. in. 1 sq. in. = 6.4516 sq. cm.

1 sq. meter = 10.76390 sq. ft. 1 sq. ft. = 0.092903 sq. m.

1 sq. km. = 0.3861 sq. mi. 1 sq. mi. = 2.58999 sq. km.
```

Cubic Measure—English¹

```
1728 cu. in = 1 cu. ft.
27 cu. ft. = 1 cu. yd.
128 cu. ft = 1 cord
50 cu. ft. of square timber = 1 load
40 cu. ft. of unhewn timber = 1 load
A board foot = 1 ft. square × 1 in. thick
```

Weight-English

```
Avoirdupois

16 drams (dr.) = 1 ounce (oz.)

16 oz. = 1 pound (lb.)

100 lb. = 1 hundred-weight (cwt.)

20 cwt. = 1 ton

Troy

24 grains = 1 pennyweight (dwt.)

20 dwt. = 1 oz. Tr.

12 oz. Tr. = 1 lb. Tr.
```

¹ For French cubic equivalents see under "Measures of Capacity."

Also in England, and the coal and iron trade in some of the colonies and the United States

112 lb. = 1 long cwt. 1 stone = 14 lb. 2240 lb. = 1 long ton

The Avoirdupois pound = 7000 grains = 14.5833 oz. Tr.
The Troy pound = 5760 grains = 13.1657 oz. Avoir.
The Avoirdupois ounce = 437.5 grains = 0.9115 oz. Tr.

1 ton = 29,166.66 oz. Tr. 1 ton = 0.89287 long ton 1 long ton = 1.12 short tons

(Troy weight is used in weighing gold, silver, platinum, etc. In weighing precious stones the metric carat = 200 mg., is now used.)

1 barrel of flour = 8 sacks = 196 lb.

1 barrel of pork = 200 lb.

1 barrel of cement = 4 sacks = 376 lb.

Weights—French

10 milligrams = 1 centigram 10 centigrams = 1 decigram 10 decigrams = 1 gram 10 grams = 1 dekagram 10 dekagrams = 1 hectogram 10 hectograms = 1 kilogram¹

100 kilograms = 1 metric quintal 1000 kilograms = 1 metric ton (tonne) or millier

Conversion Table, Weight

= 28.34954 grams1 oz. avoir. = 453.59 grams1 lb. avoir. = 907.18 kg.1 ton = 0.035274 oz. avoir. = 0.00220 lb. 1 gram 1 kg. = 35.27392 oz. avoir. = 2.2046223 lb. 1 metric ton = 1.102311 tons = 0.9842 long tons = 64.799 mg.1 grain = 1.55518 g.1 dwt. 1 oz. Troy = 31.1035 g.1 lb. Troy = 0.37324 kg.= 15.4324 gr. = 0.64301 dwt.1 gram $= 0.64301 \, \text{dwt.} = 0.03215 \, \text{oz.} \, \text{Tr.}$ 1 mg. 1 mg. = 32.15076 oz. Tr. = 2.67923 lb. Tr.

The libra used in Spain, Portugal and Spanish America differs slightly from the U.S. pound, ranging from 1.012 in Portugal and Brazil to 1.016 in Cuba and Porto Rico.

The Assay Ton.—A weight used by assayer such that 1 ton (2000 lb.):1 oz. Tr.::1 A.T.:1 mg.; i.e., if the assayer weighs

When the metric system was devised, it was intended that 1 gram should equal the mass of 1 cubic centimeter of water at its greatest density (4°C.) This relation does not exactly hold, and it is necessary to define the gram as the one-thousandth part of a standard mass of platinum kept in Paris. At 4°C. the mass of 1 cc. of water differs so slightly from unity that for nearly all calculations no correction is necessary. According to deLépinay, Benoit and Buisson, 1 kg. of water at 4°C. and 760 mm. pressure = 1000.028 c.c.

out assay tons, each milligram of metal recovered represents 1 Troy oz.

1 A.T. = 29.16667 grams

On the English system, ton of 2240 lb.

1 A.T. = 32.66667 grams

Apothecaries Weight

20 grains = 1 scruple (③) 3 ③ = 1 dram (3) 8 3 = 1 ounce (5) 12 5 = 1 lb. Tr.

Apothecaries Measure

60 minims (M) = 1 dram 8 drams = 1 fluid ounce 16 fl. oz. = 1 pt.

The apothecaries grain is equal to the Troy grain; the scruple to $\frac{5}{6}$ of the pennyweight.

1 gr. = 64.799 mg. 1 9 9 9 9 1

Measures of Capacity—English

	Dry	Liquid				
2 pt.	= 1 qt.	4 gills = 1 pt.				
8 qt.	= 1 peck	2 pt. = 1 qt.				
4 pk.	= 1 bushel	4 qt. = 1 gal.				

31½ gal. = 1 barrel (bbl.) U. S. 2 bbl. = 1 hogshead (hhd.)

 $2 \quad \text{hhd.} \qquad = 1 \text{ pipe}$

42 gal. = 1 bbl. (Standard Oil Co.), formerly a tierce

84 gal. (2 tierces) = 1 puncheon

A liquid gallon (U. S.) contains 231.0 cu. in.

An Imperial gallon contains 277.408 cu. in.

A bushel (U. S.) contains 2150.42 cu. in.

An Imperial bushel contains 2218.192 cu. in.

A quarter contains 8 Imperial bu.

NOTE.—It can be seen that the dry quart contains $67\frac{1}{2}$ cu. in., while the liquid quart contains only $57\frac{3}{2}$ cu. in. There is therefore no royal road to reducing dry measures to wet equivalents, though the ratio is about $1:1\frac{1}{6}$ (1.16364).

```
1 Imperial gal. = 1.20094 U. S. gal.

1 U. S. gal. = 0.83268 Imp. gal.

1 Imp. bu. = 1.03151 U. S. bu.

1 U. S. bu. = 0.96945 Imp. bu.

1 gal. (ale or beer) = 1.2208 U. S. gal.
```

¹ Sometimes given 277.274.

² Sometimes given 2219.28.

```
Grains per U. S. gal. \times 17.138 = parts per million
Grains per Imp. gal. \times 14.285 = parts per million
Parts per million \times 0.0583 = grains per U. S. gal.
Parts per million \times 0.700 = grains per Imp. gal.
```

Measures of Capacity—French

1000 cu. mm. = 1 c.c. 1000 c.c. = 1 cu. dm. (liter) 1000 cu. dm. = 1 cu. m.

In measuring wood, the cubic meter is called a ster.

10 milliliters = 1 centiliter
10 centiliters = 1 deciliter
10 deciliters = 1 liter
10 liters = 1 dekaliter
10 dekaliters = 1 hectoliter
10 hectoliters = 1 kiloliter

Conversion Tables, Cubic Measure

1 cu. in. = 16.38720 c.c. 1 c.c. = 0.06102376 cu. in. = 0.0000353 cu. ft. 1 cu. ft. = 0.028317 cu. m. 1 cu. m. = 35.31445 cu. ft. = 1.30794 cu. yd. 1 cu. yd. = 0.764553 cu. m.

Liquid Equivalents

1 fl. oz. = 29.57370 milliters
1 milliliter = 0.3381 fl. oz. = 0.061027 cu. in.
1 gill = 1.1829 deciliters
1 deciliter = 0.8454 gills
1 quart = 0.94636 liters
1 liter = 1.0567 quarts.
1 U. S. gal. = 3.78543 liters
1 dekaliter = 2.6417 gal.

Dry Equivalents

1 pt. = 5.5061 centiliters
1 centiliter = 0.18162 pt.
1 qt. = 1.10122 liters
1 liter = 0.90808 quarts
1 pk. = 0.08810 hectoliter
1 hectoliter = 2.8377 bu.
1 bu. (U. S.) = 0.35239 hectoliter
1 kiloliter = 1.3079 cu. yd.

Circular and Angular Measure

60 sec. (") = 1 minute (') 60 min. (') = 1 degree (°) 360 deg. (°) = 1 circumference

In the higher mathematics another unit is used:

 $2\pi \text{ radians} = 1 \text{ circumference}$ $\therefore 1 \text{ radian} = 57.2957795^{\circ} = 57^{\circ} 17' 44.806''$

Time

60 sec. = 1 min.; 60 min. = 1 hr.; 24 hr. = 1 day365.242218 solar days = 1 year29 days 12 hr. 44 min. = 1 lunar month

A seconds pendulum = 39.138 in. = 0.9958 meters in the latitude of New York at sea level.

The period of a pendulum is $\pi \sqrt{\frac{l}{a}}$, where l is length, and g the acceleration due to gravity.

Miscellaneous

20 units	= 1 score	24 sheets	= 1 quire
12 units	= 1 dozen	20 quires	
12 dozen	= 1 gross		= 1 bundle
12 gross	= 1 great gross	5 bundles	= 1 bale

1 atmosphere = 14.7 lb. per sq. in. = 29.922 in. of mercury = 33.9 ft. of water

C.G.S. Units

The unit of force is the dyne. It is that force which applied to a mass of one gram will give it an acceleration of one centimeter in one second.

The unit of work is the erg. This is the work done by one erg acting through a distance of one centimeter. The joule $= 10^7$ ergs.

A calorie is the heat necessary to raise the temperature of

1 gram of water from 0°C. to 1°C.
A great calorie (Calorie) is the heat necessary to raise the temperature of 1 kg. of water from 0°C. to 1°C.

Unit	Erg	Joule	Kilogram- meter (g. = 981)	Calorie	Small calorie
Erg	1	10-7	1.019×10 ⁻⁸	2.39011 ×10 ⁻¹¹	2.39011 ×10 ⁻⁸
Joule	107	1	1.019	2.39011 ×10 ⁻⁴	2.39011 ×10 ⁻¹
Kilogram-meter $(g. = 981)$	981.0×10 ⁵	9.81	1	2.3446 ×10 ⁻²	2.3446
Calorie	418.4×108	4184	426.5	^10 °	1000

The unit magnetic mass or pole is such that placed at a distance of one centimeter from an identical mass, it exercises a repulsion equal to 1 dyne.

The permeability is the ratio of flux density to magnetic

intensity.

The unit of electric current in the C.G.S. system is a current that exerts a force of one dyne on a unit magnetic pole placed at the center of an arc of the circuit, 1 cm. long, and 1 cm. radius. The practical unit is the ampere (see below), which is one-tenth the C.G.S. unit.

The C.G.S. unit of quantity is the quantity which in one second is conveyed by a C.G.S. unit of current. The practical unit is the coulomb, the quantity of current passing per second, in a current carrying one ampere. It is one-tenth the C.G.S. unit.

The C.G.S. unit of potential difference or electromotive force is the potential difference which exists between two points of a conductor conveying a unit current when one erg of work is done per second. The practical unit is the volt (see below) = $10^8 \times$ the C.G.S. unit.

The C.G.S. unit of resistance is the resistance possessed by a conductor through which a unit e.m.f. causes a unit current to flow. The practical unit is the ohm (see below) = $10^{9} \times \text{the}$ C.G.S. unit.

The C.G.S. unit of capacity of a condenser is that capacity which gives a unit potential difference between the coatings when either coating has a unit quantity of electricity. The farad is the practical unit and equals 10⁻⁹ times the C.G.S. unit.

A Gauss is the unit of field strength, the intensity of field which acts on a unit pole with a force of one dyne. A unit magnetic pole has 4π lines of force proceeding from it. It is equal to gilberts per centimeter length. Gausses = maxwells ÷ area.

A Maxwell is the unit of magnetic flux, the amount of magnetism passing through every square centimeter of a field of unit density. The weber is 1,000,000 maxwells. If a conductor cuts a magnetic field so that one volt is induced, 100,000,000 maxwells are cut per second.

A Gilbert is the unit of magneto-motive force, the amount produced by $\frac{10}{4\pi} = 0.7958$ ampere turns. The m.m.f. of a coil

is 1.2566 times the ampere turns. $\phi = \text{flux in maxwells.}$

Reluctance is that quantity in a magnetic circuit which limits the flux under a given m.m.f. It corresponds to the resistance in the electric circuit.

The Oersted is the unit of magnetic reluctance, it is the

reluctance of a cubic centimeter of an air-pump vacuum.

Inductance is the property of a circuit which opposes any change in current flowing by inducing a counter-electromotive force in the circuit at the time the current is changing. The practical unit is the henry (see below) = $10^9 \times \text{the C.G.S.}$ unit.

PRACTICAL ELECTRICAL UNITS

Ohm—unit of resistance. The International Ohm¹ is the resistance offered to an unvarying electric current by a column

The true ohm (=10° electromagnetic C.G.S. units) is apparently the resistance of 106.29 cm. of mercury 1 sq. cm. in section. The 1884 legal ohm = 0.9972 int'l. ohms. The B.A. ohm = 0.9866 int'l. ohm.

A joule is almost equal to the energy expended in one second by an international ampere in an international ohm.

of mercury at 0°C., 14.4521 grams in mass, of a constant cross section, and of a length of 106.3 cm.

Coulomb—unit of quantity. Equal to one ampere passing

for one second.

Ampere—unit of current. The International Ampere is the unvarying electric current which, when passed through a solution of nitrate of silver in water, under certain specifications, deposits silver at the rate of 0.00111800 grams per second.

International Volt—unit of pressure. It is that electrical pressure which will steadily produce a one-ampere current through a one-ampere resistance. For practical use it is $\frac{1000}{1434}$ of the e.m.f. of the Clark cell at 15°C.

International Watt—unit of energy. It is the energy expended per second by an unvarying electric current of one International Ampere under an electric pressure of an Inter-

national Volt.

International Farad—unit of capacity. It is the capacity of a conductor which is charged to a potential of one volt by

one coulomb of electricity.

International Henry—unit of inductance. It is the inductance in the circuit when the e.m.f. induced in the circuit is one international volt, while the inducing current varies at the rate of one international ampere per second.

Ohm's Law.—Current in amperes =

$$\frac{\text{Pressure in volts}}{\text{Resistance in ohms}} \text{ or } I = \frac{E}{R}$$

Power in watts equals energy of the current multiplied by the voltage.

Direct current—P (watts = E (volts) $\times I$ (amperes)

$$=\frac{E^2}{R}=IR^2$$

Alternating current—

single-phase, $P = EI \times Power factor$

two-phase, $P = \sqrt{2EI} \times \text{Power factor (line values; two wire)}$

three-phase, $P = \sqrt{3}EI \times \text{Power factor}$ (line values; three wire)

Units of Force

1 poundal = 13,825 dynes 1 gram's weight = 980 dynes 1 pound's weight = 444,518 dynes

Work and Energy

1 foot-pound = 1.383×10^7 ergs = 1.383 joules = 0.1383 kilogram-meters

1 watt = 1 joule per second 1 kilogram-meter = 7.283 foot-pounds

Weight, Force or Pressure, Combined with Areas

1 atmosphere = 760 mm. of mercury = 29.9212 in. of mercury

= 10.3329 m. of water = 33.9006 ft. of water

= 1.03329 kg. per sq. cm. = 14.6969 lb. per sq. in.

1 barie = 1 dyne per sq. cm. = 0.00208870 lb. per sq. ft. 1 foot-pound = 13.8255 kg. cm. = 3.306×10^{-4} cal.

1 kg. per sq. m. = 14.2234 lb. per sq. in.

1 lb. carbon oxidized to CO₂ = 14,544 heat units.

TABLE OF EQUIVALENT VALUES FOR POWER EXPRESSED IN VARIOUS ENGLISH AND METRIC UNITS

	Watt	Kw.	English h.p.	Continuental	Kgm. per sec.	Ftlb. per sec.	Kg cal. per sec.	B.t.u. per sec.
1 watt is equal to 1 kw. is equal		0.001000	0.00134	0.00136	0.102	0.737	0.000238	0.000947
to 1 English (and Amer-	1000.0	1.000	1.34	1.36	102.0	737.0	0.238	0.947
ican) h.p 1 Continen-	746.0	0.746	1.000	1.015	76.0	550.0	0.178	0.707
tal h.p 1 kgm. per	735.0	0.735	0.985	1.000	75.0	541.0	0.175	0.696
sec 1 ftlb. per	9.81	0.00981	0.0131	0.0133	1.000	7.233	0.00234	0.00930′
sec	1.356	0.00136	0.00182	0.00185	0.138	1.000	0.000324	0.00129
1 kgcal. per	4200.0	4.20	5.61	5.70	427.0	3090.0	1.000	3.968
1 B.t.u. per	1055.0	1.055	0.415	0.422	107.6	778.0	0.252	1.000

Light—velocity of, 299,583 km. per sec. = 186,319 mi. per sec. Wave length, red light—B line—0.000068702 cm. Wave length, violet light—K line—0.000039338 cm. Velocity of sound in dry air = $1090\sqrt{1+0.00367}$ t°C. ft. per sec.

Some Foreign Weights and Measures and the U.S. Equivalents¹

= 4.422 gal.1 almude (Portugal) 1 arobe (Paraguay) = 25 lb.1 arroba, dry (Argentine) = 25.3171 lb.1 arroba, liquid (Cuba, Spain, = 4.263 gal.Venezuela) 1 arshine (Russia) = 28 in.1 sq. arshine (Russia) = 5.44 sq. ft.1 baril (Argentine, Mexico) = 20.079 gal.= 2.407 yards1 braca (Brazil) = 0.119305 in.1 bu (Japan) = 529 lb.1 candy (India)

¹ "Foreign Weights, Measures and Moneys." By John J. Macfarlane.

```
1 catty (China, Str. Sett.)
                                   = 1.333 \, lb.
1 catty (Japan)
                                   = 1.323 \text{ lb.}
1 catty (Java)
1 catty (P. I.)
                                   = 1.356 lb.
                                   = 1.39 lb.
1 catty (Sumatra)
                                   = 2.118 lb.
1 centaro (Central America) = 4.2631 gal.
1 chih (China)
                                  = 1.049867 \, \text{ft.}
1 cho (Japan)
                                   = 357.916 ft.
1 cuadra (Argentine)
                                   = 4.2 \text{ acres}
                                   = 2.6997 \text{ acres}
1 dessiatine (Russia)
1 doli (Russia)
                                   = 0.685 grains
1 fanega (Argentine)
                                   = 3.89 \text{ bu}.
                                   = 0.12598 \text{ in.}
1 fen (China)
1 fen (sq.) (China)
                                   = 0.015181 \text{ acres}
1 frasco (Argentine)
                                   = 2.5096 quarts
1 funt (Russia)
                                   = 0.9028 \text{ lb.} = 409 \text{ grams}
                                   = 1.270506 gill liquid =
1 go (Japan)
                                      0.0198517 peck dry
                                   = 2.5715 \, \text{ft}.
1 hao (China)
1 sq. hao (China)
                                   = 0.00015181 acres
                                   = 3.31404 yd.
= 1.983427 yd.
1 jo (Japan)
1 ken (Japan)
                                   = 1.32277 lb. Avoir.
1 kin (Japan)
                                 = 39.7033 gal. liquid =
1 koku (Japan)
                                      4.96291 bu. dry
1 kwan (Japan)
                                  = 8.26733 lb. Avoir.
1 legua (Brazil)
                                   = 4.102 miles
1 li (China)
                                   = 0.012598 \text{ in.}
1 liang (China)
                                   = 1.31561 oz. Avoir.
1 lyi (China)
                                   = 0.0015181 \text{ acres}
                                 = 1.625 acres
1 manzana (Costa Rica)
1 marc (Bolivia)
                                  = 0.507 \text{ lb.}
1 maund (Bengal)
1 maund (Bombay)
1 maund (Madras)
                                  = 82.2855  lb.
                                  = 28 lb.
                                  = 25 lb.
1 meou (China)
                                  = 0.15181 \, \text{acres}
1 mil (Denmark)
                                   = 4.68 \text{ mi.}
1 milla (Nicaragua, Honduras) = 1.1493 miles
1 momme (Japan)
                                 = 2.4123045 \, dwt.
1 pie (Argentine)
                                   = 0.9478 \, \text{ft.}
1 pie (Spain)
                                   = 0.91407 \, \text{ft.}
1 pikul (Borneo, Java)
1 pikul (China, Str. Sett.)
                                   = 135.6354 lb.
                                   = 133\frac{1}{3} lb.
1 pikul (Japan)
                                   = 132.277 lb.
                                   = 139.485 lb.
1 pikul (P. I.)
1 pipa (Brazil)
                                   = 1.648 quarts
1 pood (Russia)
                                  = 36.1128 lb.
1 pulgada (Argentine)
                                   = 0.947 in.
1 quintal (Argentina)
1 quintal (Bolivia, Chile, Co-
                                   = 101.28 \text{ lb.}
  lombia, Domin. Rep., Spain) = 101.4 lb.
1 quintal (Brazil)
                             = 129.526 \text{ lb.}
```

```
1 quintal (Costa Rica)
                                    = 101.465 lb.
1 quintal (Syria, Turkey)
                                    = 125 lb.
                                    = 2.440338 \text{ mi.}
1 ri (Japan)
1 ri (marine) (Japan)
                                    = 1.1506873 \text{ mi.}
                                    = 7 \text{ ft.}
1 sagene (Russia)
                                    = 7 lb.
1 sashen (Russia)
1 shaku (Japan)
                                    = 11.9305424 \text{ in.}
                                    = 2.7354 \text{ liq. gal.}
1 sheng (China)
1 sho (Japan)
                                    = 1.5881325 \, \text{qt. liquid} =
                                       0.1985166 pecks dry
1 sun (Japan)
                                    = 1.1930542 \text{ in}.
1 tan (Japan)
                                    = 0.24507 acre
1 tch'e (China)
                                    = 12.598 \text{ in.}
                                    = 117,600 \text{ sq. ft.}
1 tchetvert (Russia)
                                    = 3.9703313 gal. liquid
1 to (Japan)
1 ts'onen (China)
                                    = 1.2598 \text{ in.}
                                    = 3.953829 \text{ sq. yd.}
1 tsubo (Japan)
1 vara (Argentine)
                                    = 34.1208 in.
                                    = 1.75 \text{ in.}
1 verchok (Russia)
                                    = 3,500 \text{ ft.}
1 verst (Russia)
1 zolotnik (Russia)
                                    = 658 grains
```

UNITED STATES AND FOREIGN MONEY

(The following figures are based on the gold standard only and do not include exchange.)

```
= 100 centavos
Argentina (gold)
                                      = $0.9648
                      1 peso
                                      = 0.4246 = 100 \text{ centavos}
Argentina (paper)
                      1 peso
                      1 krone
                                     -0.203
                                                   = 100 heller
Austria
                                     -0.3893
                                                  = 100 centavos
Bolivia
                      1 boliviano
                                                  = 1000 reis
· Brazil
                      1 milreis
                                      -0.5463
Ceylon
                                      = 0.32443 = 100  cents
                      1 rupee
                      1 peso = 0.365 = 100 centavos

1 Haikwan tael = 1½ oz. avoir. of silver = 10 mace

1 peso = 1.00 = 100 centavos
Chile
 China
 Columbian Rep'b. 1 peso

0.4654
0.268

                                                 = 100 centavos
= 100 öre
                      1 colon
 Costa Rica
                      1 krone
 Denmark
                                      -0.4867
                                                   = 100 centavos
Ecuador
                      1 sucre
Egypt
                     1 pound (£E) = 4.943
                                                   = 100 piastres
                                      = 1000 milliemes
                      1 franc = 0.193 = 100 centimes

1 mark = 0.238 = 100 pfennig

1 pound (£) = 4.8665 = 20 shillings = 240 pence<sup>1</sup>
 France
 Germany
 Great Britain
                      1 drachma
 Greece
                                      = 0.193
                                                   = 100 lepta
                                                   = 100 centavos
= 100 centimes
 Guatemala
                                      -0.965
                      1 peso
 Haiti
                      1 gourde
                                      -0.965
                                      -0.3979
                                                   = 100 centavos
 Honduras
                      1 peso
                      1 dollar
                                                   = 100 \text{ cents} = 1000 \text{ cash}
                                      -0.463
 Hongkong
                                      -0.2026
 Hungary
                      1 krone
                                                   = 100 filler
                      1 rupee (Rs.) = 0.32443 = 16 annas = 192 pies<sup>2</sup>
 India
                                     -0.193
                                                   = 100 centesimos
 Italy
                      1 lira
                                     -0.498
                                                   = 100 \text{ sen} = 1000 \text{ rin}
                      1 yen
 Japan
                                                  = 100 centavos
 Mexico
                      1 peso
                                      -0.498
                                                   = 100 cents
 Netherlands
                      1 guilder
                                      -0.0402
                      1 peso
1 krone
                                      -0.965
                                                   = 100 centavos
 Nicaragua
                                      -0.268
                                                   = 100 öre
 Norway
Panama
                      1 balboa
                                                   = 2 silver pesos
                                      -1.00
                                      = 200 centisimos
Peru
                      1 libra (£P)
                                    = 4.8665 = 10 \text{ dinero} = 100 \text{ centavos}
   15 shillings = 1 crown; 21 sh. = 1 guinea; 4 farthings = 1 penny (d.).
   <sup>2</sup> A lakh = 100,000 rupees; a crore = 10,000,000 rupees.
```

Philippine Is.	1 peso	=	0.50		100 centavos	
Portugal	1 milreis	-	1.08	=	1000 reis	
Roumania	1 leu	-	0.193		100 bani	
Russia	1 ruble		0.515	=	100 kopecks	
Salvador	1 peso		0.3978		100 centavos	
Spain	1 peseta		0.193	=	100 centisimos	
Straits Settlements	1 dollar	=	0.5677	95	100 cents	
Sweden	1 krona	=	0.268	=	100 ŏre	
Turkey	1 pound (£T)		4.40	==	100 piasters = 4000 para	8
Uruguay	1 peso	238	1.0342		100 centavos	
Venezuela	1 bolivar	=	0.1930	=	100 centimos	

COINAGE STANDARDS1

Country	Gold coin	Silver coin	Country	Gold	Silver coin
Abyssinia		835	Honduras		900
Argentine					925
Austria-Hungary			Hongkong		800
Belgium			India	916.6	916.6
Bolivia			Italy		900,835
	916.6				
	900.0	900,835			800
Canada		925			902.7,800
Ceylon		800			900,835
Chile	916.6		Newfoundland		925
China		900,866,820	Nicaragua		800
Colombia		900,835		900.0	
Congo	900.0		Panama		900
Corea		800	Paraguay	:::::	900
Costa Rica		900	Persia	900.0	900
	900.0		Peru		
Curação	• • • •	640			
Cyprus	::::	925		900.0	900,835
Denmark	900.0	800,600,400		900.0	900,500
Dominica		900,835		900.0	900,835
Dutch East Indies	1	720		900.0	
	900.0			010 0	900
	875.0	000.0		916.6	
	900.0	000,700	Spain		900,835
	900.0	900,000			800,600,400
	916.0	900	Straits Settlements Switzerland	000	900,800
<u> </u>	900.0		Turkey		900.835 830
Greece	900.0		United States		
Hayti	900.0	000,000	Uruguay	500.0	900
Holland	900.0		Venezuela	ann n	
ALVIIGIIVI	300.0	010,010	TOROZUCIO		300,000

ALGEBRA

Powers and Roots

According to the binomial theorem

$$(a+b)^{K} = a^{K} + Ka^{K-1}b + \frac{K(K-1)}{1\cdot 2}a^{K-2}b^{2} + \frac{K(k-1)(k-2)}{1\cdot 2\cdot 3}a^{K-3}b^{3} + \dots + \frac{K(K-1)(k-2)}{1\cdot 2\cdot 3}a^{K-3}b^{K-2} + \frac{K(K-1)(k-2)}{1\cdot 2\cdot 3}a^{K-3}b^{K-1} + b^{K}$$

1 T. K. Rose, "Precious Metals."

This formula will serve for the solution of any power whatever, and will, in general, serve to indicate the process of the extraction of roots. However, for all practical work on roots and powers, use the table of logarithms on p. 42.

$$\log a^{x} = k \log a$$
$$\log^{k} \sqrt{a} = \frac{\log a}{k}$$

Permutation, Choice and Chance

The number of different arrangements (or permutations) of n different things taken altogether is factorial n.

$$(n! \text{ or } | \underline{n} = n(n-1) (n-2) \dots 3 \times 2 \times 1)$$

The number of different selections (or combinations) of n different things taken r at a time is:

$$\frac{n(n-1) (n-2) \dots (n-r+1)}{|\underline{r}|}$$

The number of selections of n things taken r at a time is the same as the number of selections of n things taken n - r at a time.

The number of selection of n things taken r at a time is greatest when: If n is an odd number,

$$r=\frac{n-1}{2}$$

if n is an even number

$$r=\frac{n}{2}$$

The chance of an event happening is expressed by the fraction of which the numerator is the number of favorable ways, and the denominator the whole number of ways, favorable and unfavorable.

If there are several events of which one, and only one can happen, the chance that one will happen is the sum of the respective chances of happening.

Progression

The chief "progressions" are arithmetical, geometrical, and harmonic. They are series of numbers in which a common law connects the successive terms.

Arithmetical progression in a series of numbers consists in a constant difference between the successive terms, as

1, 3, 5, 7, 9, . . . Let a =first term; l =last term; d =the common difference; n =the number of terms; s =the sum of the terms.

$$l = a + (n-1)d = \frac{2s}{n} - a = \frac{s}{n} + \frac{(n-1)d}{2} = -\frac{1}{2}d \pm \sqrt{2ds + \left(a - \frac{d}{2}\right)^2}$$

$$\frac{s}{2} = \frac{n}{2} \left[2a + (n-1)d \right] = \frac{n}{2} (l+a) = \frac{n}{2} \left[2l - (n-1)d \right] = \frac{l+a}{2} \left(\frac{d+l-a}{d} \right)$$

$$a = l - (n-1)d = \frac{2s}{n} - l = \frac{s}{n} - \frac{(n-1)d}{2} = \frac{1}{2}d \pm \sqrt{\left(l+\frac{d}{2}\right)^2 - 2ds}$$

$$d = \frac{l-a}{n-1} = \frac{2(s-an)}{n(n-1)} = \frac{l^2-a^2}{2s-l-a} = \frac{2(nl-s)}{n(n-1)}$$

$$n = \frac{l-a}{d} + 1 = \frac{2s}{l+a} = \frac{d-2a \pm \sqrt{(2a-d)^2 + 8ds}}{2d} = \frac{2l+d \pm \sqrt{(2l+d)^2 - 8ds}}{2d}$$

Geometrical progression in a series of numbers consists in a constant ratio existing between the successive terms, as

4, 8, 16, 32, . . . Let a =first term; l =last term; m =any (middle) term; s =sum; r =ratio or constant multiplier.

$$l = ar^{n-1} = \frac{a + (r-1)s}{r} = \frac{(r-1)sr^{n-1}}{r^{n-1}}$$

$$m = ar^{m-1}$$

$$s = \frac{a(r^n - 1)}{r - 1} = \frac{rl - a}{r - 1} = \frac{n - 1\sqrt{l^n} - n - 1\sqrt{a^n}}{n - 1\sqrt{l} - n - 1\sqrt{a}} = \frac{lr^n - l}{r^n - r^{n-1}}$$

$$a = \frac{l}{r^{n-1}} = \frac{(r-1)s}{r^{n-1}} = rl - (r-1)s$$

$$r = \sqrt{\frac{l}{a}} = \frac{s - a}{s - l}$$

$$r^n - \frac{s}{a}r + \frac{s - a}{a} = r^n - \frac{s}{s - l}r^{n-1} + \frac{l}{s - l} \equiv 0$$

Harmonic series is one in which the numbers are the reciprocals of those forming an arithmetical progression. Such series are of small practical value, and such questions as arise in them, when solvable, are best answered by inverting the series, and solving as a problem in arithmetical progression. In ancient times a fictitious importance was attached to them owing to the fact that a series of rods of uniform cross-section having lengths in harmonic progression form a musical scale, hence the name.

INTEREST, ANNUITIES, SINKING FUNDS Simple Interest

If the principal be represented by the interest on \$1 for one year by the amount of \$1 for one year by the number of years by the amount of P after n years by A

Then R = 1 + rSimple interest on P for one year = PrSimple interest on I for one year I = A = P(1 + nr)that is

When any three of the quantities A, P, n, r, are given, the

fourth may be found from this last equation.

Since P will in n years at r interest amount to A, P may be considered equivalent in value to A at the end of n years; in other words, P is the "present worth" of A.

Compound Interest

When compound interest is reckoned payable annually. The amount of P dollars in

1 year is
$$P(1 + r) = PR$$

2 years is $PR(1 + r) = PR^2$
n years $= PR^n$
or $A = PR^n$ or $P = \frac{A}{R^n}$

When compound interest is reckoned semi-annually. The amount of P dollars in

1/2 year is
$$P\left(1 + \frac{r}{2}\right)$$
1 year is $P\left(1 + \frac{r}{2}\right)^2$
 $n \text{ years, } A = P\left(1 + \frac{r}{2}\right)^{2n}$

When the interest is payable quarterly

$$A = P\left(1 + \frac{r}{4}\right)^{4n}$$

$$A = P\left(1 + \frac{r}{12}\right)^{12n}$$

When the interest is payable quarterly $A = P\left(1 + \frac{r}{4}\right)^{4n}$ When the interest is payable monthly $A = P\left(1 + \frac{r}{12}\right)^{12n}$ -And when the interest is payable q times a year

$$A = P\left(1 + \frac{r}{q}\right)^{qn}$$

Sinking Funds

If the sum set apart at the end of each year to be put at compound interest be represented by S, then, the sum at the end of the

first year =
$$S$$

second year = $S + SR$
third year = $S + SR + SR^2$
 n th year = $S + SR + SR^2$. . . SR^{n-1}
 $A = S + SR + SR^2$. . . $+ SR^{n-1}$
 $\therefore AR = SR + SR^2$. . . $+ SR^{n-1} + SR^n$
 $\therefore AR - A = SR^n - S$
 $A = \frac{S(R^n - 1)}{R - 1} = S\frac{(R^n - 1)}{r}$

COMPOUND INTEREST AND DISCOUNT TABLES

Years Am't of \$1 in n yrs. resent val. of \$1 annum in n yrs. resent val. of \$1 annum in n yrs. Am't val. of \$1 annum in n yrs. Am't val. of \$1 annum in n yrs. Am't val. of \$1 due in n yrs. yrs. \$1 due in n yrs.	
2 1.040 .9612 2.06 1.980 1.051 .9518 2.08 3 1.061 .9423 3.12 2.942 1.077 .9286 3.15 4 1.082 .9238 4.20 3.884 1.104 .9060 4.26 5 1.104 .9057 5.31 4.808 1.131 .8839 5.39 6 1.126 .8880 6.43 5.713 1.160 .8623 6.55 7 1.149 .8706 7.58 6.601 1.189 .8413 7.74 8 1.172 .8535 8.75 7.472 1.218 .8207 8.95 9 1.195 .8368 9.95 8.325 1.249 .8007 10.20 10 1.219 .8203 11.17 9.162 1.280 .7812 11.48 11 1.243 .8043 12.41 9.983 1.312 .7621 12.80 12 1.268 .7885 13.68 10.787 1.345 .7436 14.14 1	resent val. of il an- nuity for n yrs.
3 1.061 .9423 3.12 2.942 1.077 .9286 3.15 4 1.082 .9238 4.20 3.884 1.104 .9060 4.26 5 1.104 .9057 5.31 4.808 1.131 .8839 5.39 6 1.126 .8880 6.43 5.713 1.160 .8623 6.55 7 1.149 .8706 7.58 6.601 1.189 .8413 7.74 8 1.172 .8535 8.75 7.472 1.218 .8207 8.95 9 1.195 .8368 9.95 8.325 1.249 .8007 10.20 10 1.219 .8203 11.17 9.162 1.280 .7812 11.48 11 1.243 .8043 12.41 9.983 1.312 .7621 12.80 12 1.268 .7885 13.68 10.787 1.345 .7436 14.14 1 13 1.294 .7730 14.97 11.575 1.379 .7254 15.52 1	1.000 1.976
5 1.104 .9057 5.31 4.808 1.131 .8839 5.39 6 1.126 .8880 6.43 5.713 1.160 .8623 6.55 7 1.149 .8706 7.58 6.601 1.189 .8413 7.74 8 1.172 .8535 8.75 7.472 1.218 .8207 8.95 9 1.195 .8368 9.95 8.325 1.249 .8007 10.20 10 1.219 .8203 11.17 9.162 1.280 .7812 11.48 11 1.243 .8043 12.41 9.983 1.312 .7621 12.80 12 1.268 .7885 13.68 10.787 1.345 .7436 14.14 1 13 1.294 .7730 14.97 11.575 1.379 .7254 15.52 1 14 1.319 .7579 16.29 12.348 1.413 .7077 16.93 1 <td>2.927</td>	2.927
6 1.126 .8880 6.43 5.713 1.160 .8623 6.55 7 1.149 .8706 7.58 6.601 1.189 .8413 7.74 8 1.172 .8535 8.75 7.472 1.218 .8207 8.95 9 1.195 .8368 9.95 8.325 1.249 .8067 10.20 10 1.219 .8203 11.17 9.162 1.280 .7812 11.48 11 1.243 .8043 12.41 9.983 1.312 .7621 12.80 12 1.268 .7885 13.68 10.787 1.345 .7436 14.14 1 13 1.294 .7730 14.97 11.575 1.379 .7254 15.52 1 14 1.319 .7579 16.29 12.348 1.413 .7077 16.93 1 15 1.346 .7430 17.64 13.106 1.448 .6905 18.38 1 16 1.373 .7284 19.01 13.849 1.485	3.856 4.762
7 1.149 .8706 7.58 6.601 1.189 .8413 7.74 8 1.172 .8535 8.75 7.472 1.218 .8207 8.95 9 1.195 .8368 9.95 8.325 1.249 .8067 10.20 10 1.219 .8203 11.17 9.162 1.280 .7812 11.48 11 1.243 .8043 12.41 9.983 1.312 .7621 12.80 12 1.268 .7885 13.68 10.787 1.345 .7436 14.14 1 13 1.294 .7730 14.97 11.575 1.379 .7254 15.52 1 14 1.319 .7579 16.29 12.348 1.413 .7077 16.93 1 15 1.346 .7430 17.64 13.106 1.448 .6905 18.38 1 16 1.373 .7284 19.01 13.849 1.485 .6736	5.646
8 1.172 .8535 8.75 7.472 1.218 .8207 8.95 9 1.195 .8368 9.95 8.325 1.249 .8007 10.20 10 1.219 .8203 11.17 9.162 1.280 .7812 11.48 11 1.243 .8043 12.41 9.983 1.312 .7621 12.80 12 1.268 .7885 13.68 10.787 1.345 .7436 14.14 1 13 1.294 .7730 14.97 11.575 1.379 .7254 15.52 1 14 1.319 .7579 16.29 12.348 1.413 .7077 16.93 1 15 1.346 .7430 17.64 13.106 1.448 .6905 18.38 1 16 1.373 .7284 19.01 13.849 1.485 .6736 19.86 1 17 1.400 .7142 20.41 14.578 1.522 .6572 21.39 1 18 1.428 .7002 21.84	6.508
10 1.219 .8203 11.17 9.162 1.280 .7812 11.48 11 1.243 .8043 12.41 9.983 1.312 .7621 12.80 12 1.268 .7885 13.68 10.787 1.345 .7436 14.14 1 13 1.294 .7730 14.97 11.575 1.379 .7254 15.52 1 14 1.319 .7579 16.29 12.348 1.413 .7077 16.93 1 15 1.346 .7430 17.64 13.106 1.448 .6905 18.38 1 16 1.373 .7284 19.01 13.849 1.485 .6736 19.86 1 17 1.400 .7142 20.41 14.578 1.522 .6572 21.39 1 18 1.428 .7002 21.84 15.292 1.560 .6412 22.95 1 19 1.457 .6864 23.30 15.992 1.599 .6255 24.54 1 20 1.486	7.349
11 1.243 .8043 12.41 9.983 1.312 .7621 12.80 12 1.268 .7885 13.68 10.787 1.345 .7436 14.14 1 13 1.294 .7730 14.97 11.575 1.379 .7254 15.52 1 14 1.319 .7579 16.29 12.348 1.413 .7077 16.93 1 15 1.346 .7430 17.64 13.106 1.448 .6905 18.38 1 16 1.373 .7284 19.01 13.849 1.485 .6736 19.86 1 17 1.400 .7142 20.41 14.578 1.522 .6572 21.39 1 18 1.428 .7002 21.84 15.292 1.560 .6412 22.95 1 19 1.457 .6864 23.30 15.992 1.599 .6255 24.54 1 20 1.486 .6730 24.78 16.678 1.639 .6103 26.18 1 21	8.170
12 1.268 .7885 13.68 10.787 1.345 .7436 14.14 1 13 1.294 .7730 14.97 11.575 1.379 .7254 15.52 1 14 1.319 .7579 16.29 12.348 1.413 .7077 16.93 1 15 1.346 .7430 17.64 13.106 1.448 .6905 18.38 1 16 1.373 .7284 19.01 13.849 1.485 .6736 19.86 1 17 1.400 .7142 20.41 14.578 1.522 .6572 21.39 1 18 1.428 .7002 21.84 15.292 1.560 .6412 22.95 1 19 1.457 .6864 23.30 15.992 1.599 .6255 24.54 1 20 1.486 .6730 24.78 16.678 1.639 .6103 26.18 1 21 1.516 .6598 26.30 17.351 1.680 .5954 27.86 1	8.971
13 1.294 .7730 14.97 11.575 1.379 .7254 15.52 1 14 1.319 .7579 16.29 12.348 1.413 .7077 16.93 1 15 1.346 .7430 17.64 13.106 1.448 .6905 18.38 1 16 1.373 .7284 19.01 13.849 1.485 .6736 19.86 1 17 1.400 .7142 20.41 14.578 1.522 .6572 21.39 1 18 1.428 .7002 21.84 15.292 1.560 .6412 22.95 1 19 1.457 .6864 23.30 15.992 1.599 .6255 24.54 1 20 1.486 .6730 24.78 16.678 1.639 .6103 26.18 1 21 1.516 .6598 26.30 17.351 1.680 .5954 27.86 1 22 1.546	9.752 10.514
15 1.346 .7430 17.64 13.106 1.448 .6905 18.38 1 16 1.373 .7284 19.01 13.849 1.485 .6736 19.86 1 17 1.400 .7142 20.41 14.578 1.522 .6572 21.39 1 18 1.428 .7002 21.84 15.292 1.560 .6412 22.95 1 19 1.457 .6864 23.30 15.992 1.599 .6255 24.54 1 20 1.486 .6730 24.78 16.678 1.639 .6103 26.18 1 21 1.516 .6598 26.30 17.351 1.680 .5954 27.86 1 22 1.546 .6468 27.84 18.011 1.722 .5809 29.58 1 23 1.577 .6342 29.42 18.658 1.765 .5667 31.35 1 24 1.608 .6217 31.03 19.292 1.809 .5529 33.16 1	1.258
16 1.373 .7284 19.01 13.849 1.485 .6736 19.86 1 17 1.400 .7142 20.41 14.578 1.522 .6572 21.39 1 18 1.428 .7002 21.84 15.292 1.560 .6412 22.95 1 19 1.457 .6864 23.30 15.992 1.599 .6255 24.54 1 20 1.486 .6730 24.78 16.678 1.639 .6103 26.18 1 21 1.516 .6598 26.30 17.351 1.680 .5954 27.86 1 22 1.546 .6468 27.84 18.011 1.722 .5809 29.58 1 23 1.577 .6342 29.42 18.658 1.765 .5667 31.35 1 24 1.608 .6217 31.03 19.292 1.809 .5529 33.16 1 25 1.641 .6095 32.67 19.914 1.854 .5394 35.01 1	1.983
17 1.400 .7142 20.41 14.578 1.522 .6572 21.39 1 18 1.428 .7002 21.84 15.292 1.560 .6412 22.95 1 19 1.457 .6864 23.30 15.992 1.599 .6255 24.54 1 20 1.486 .6730 24.78 16.678 1.639 .6103 26.18 1 21 1.516 .6598 26.30 17.351 1.680 .5954 27.86 1 22 1.546 .6468 27.84 18.011 1.722 .5809 29.58 1 23 1.577 .6342 29.42 18.658 1.765 .5667 31.35 1 24 1.608 .6217 31.03 19.292 1.809 .5529 33.16 1 25 1.641 .6095 32.67 19.914 1.854 .5394 35.01 1 26 1.673 .5976 34.34 20.523 1.900 .5262 36.91 1	2.691
18 1.428 .7002 21.84 15.292 1.560 .6412 22.95 1 19 1.457 .6864 23.30 15.992 1.599 .6255 24.54 1 20 1.486 .6730 24.78 16.678 1.639 .6103 26.18 1 21 1.516 .6598 26.30 17.351 1.680 .5954 27.86 1 22 1.546 .6468 27.84 18.011 1.722 .5809 29.58 1 23 1.577 .6342 29.42 18.658 1.765 .5667 31.35 1 24 1.608 .6217 31.03 19.292 1.809 .5529 33.16 1 25 1.641 .6095 32.67 19.914 1.854 .5394 35.01 1 26 1.673 .5976 34.34 20.523 1.900 .5262 36.91 1 27 1.707 .5859 36.05 21.121 1.948 .5134 38.86 1	l3.381 l4.055
19 1.457 .6864 23.30 15.992 1.599 .6255 24.54 1 20 1.486 .6730 24.78 16.678 1.639 .6103 26.18 1 21 1.516 .6598 26.30 17.351 1.680 .5954 27.86 1 22 1.546 .6468 27.84 18.011 1.722 .5809 29.58 1 23 1.577 .6342 29.42 18.658 1.765 .5667 31.35 1 24 1.608 .6217 31.03 19.292 1.809 .5529 33.16 1 25 1.641 .6095 32.67 19.914 1.854 .5394 35.01 1 26 1.673 .5976 34.34 20.523 1.900 .5262 36.91 1 27 1.707 .5859 36.05 21.121 1.948 .5134 38.86 1 28 1.741 .5744 37.79 21.707 1.996 .5009 40.86 2	4.712
21 1.516 .6598 26.30 17.351 1.680 .5954 27.86 1 22 1.546 .6468 27.84 18.011 1.722 .5809 29.58 1 23 1.577 .6342 29.42 18.658 1.765 .5667 31.35 1 24 1.608 .6217 31.03 19.292 1.809 .5529 33.16 1 25 1.641 .6095 32.67 19.914 1.854 .5394 35.01 1 26 1.673 .5976 34.34 20.523 1.900 .5262 36.91 1 27 1.707 .5859 36.05 21.121 1.948 .5134 38.86 1 28 1.741 .5744 37.79 21.707 1.996 .5009 40.86 2 29 1.776 .5631 39.57 22.281 2.046 .4887 42.90 2 30 1.811 .5521 41.38 22.844 2.098 .4767 45.00 2 <th>l5.353</th>	l5.3 53
22 1.546 .6468 27.84 18.011 1.722 .5809 29.58 1 23 1.577 .6342 29.42 18.658 1.765 .5667 31.35 1 24 1.608 .6217 31.03 19.292 1.809 .5529 33.16 1 25 1.641 .6095 32.67 19.914 1.854 .5394 35.01 1 26 1.673 .5976 34.34 20.523 1.900 .5262 36.91 1 27 1.707 .5859 36.05 21.121 1.948 .5134 38.86 1 28 1.741 .5744 37.79 21.707 1.996 .5009 40.86 2 29 1.776 .5631 39.57 22.281 2.046 .4887 42.90 2 30 1.811 .5521 41.38 22.844 2.098 .4767 45.00 2	15.979
23 1.577 .6342 29.42 18.658 1.765 .5667 31.35 1 24 1.608 .6217 31.03 19.292 1.809 .5529 33.16 1 25 1.641 .6095 32.67 19.914 1.854 .5394 35.01 1 26 1.673 .5976 34.34 20.523 1.900 .5262 36.91 1 27 1.707 .5859 36.05 21.121 1.948 .5134 38.86 1 28 1.741 .5744 37.79 21.707 1.996 .5009 40.86 2 29 1.776 .5631 39.57 22.281 2.046 .4887 42.90 2 30 1.811 .5521 41.38 22.844 2.098 .4767 45.00 2	l6.589 l7.185
24 1.608 .6217 31.03 19.292 1.809 .5529 33.16 1 25 1.641 .6095 32.67 19.914 1.854 .5394 35.01 1 26 1.673 .5976 34.34 20.523 1.900 .5262 36.91 1 27 1.707 .5859 36.05 21.121 1.948 .5134 38.86 1 28 1.741 .5744 37.79 21.707 1.996 .5009 40.86 2 29 1.776 .5631 39.57 22.281 2.046 .4887 42.90 2 30 1.811 .5521 41.38 22.844 2.098 .4767 45.00 2	7.765
26 1.673 .5976 34.34 20.523 1.900 .5262 36.91 1 27 1.707 .5859 36.05 21.121 1.948 .5134 38.86 1 28 1.741 .5744 37.79 21.707 1.996 .5009 40.86 2 29 1.776 .5631 39.57 22.281 2.046 .4887 42.90 2 30 1.811 .5521 41.38 22.844 2.098 .4767 45.00 2	18.332
27 1.707 .5859 36.05 21.121 1.948 .5134 38.86 1 28 1.741 .5744 37.79 21.707 1.996 .5009 40.86 2 29 1.776 .5631 39.57 22.281 2.046 .4887 42.90 2 30 1.811 .5521 41.38 22.844 2.098 .4767 45.00 2	18.885
28 1.741 .5744 37.79 21.707 1.996 .5009 40.86 2 29 1.776 .5631 39.57 22.281 2.046 .4887 42.90 2 30 1.811 .5521 41.38 22.844 2.098 .4767 45.00 2	19.424
29 1.776 .5631 39.57 22.281 2.046 .4887 42.90 2 30 1.811 .5521 41.38 22.844 2.098 .4767 45.00 2	l9.951 20.464
	20.965
- 31 1 848 5412 43 22 23 396 2 150 4651 47 15 9	21.454
	21.930
	22.39 5 22.8 49
34 1.961 .5100 48.99 24.989 2.315 .4319 53.93 2	23.292
	23.724
36 2.040 .4902 53.03 25.999 2.433 .4111 58.73 2	24.145
	24 . 55 6 24 . 957
	25.349
40 2.208 .4529 61.61 27.903 2.685 .3724 69.09 2	25. 730
41 2.252 .4440 63.86 28.355 2.752 .3633 71.84 2	26.103
	26.46 6 26.821
	27.166
	7.504
	7.833
	28.1 54 ` 28.46 7
	28.773
	29.071

For interest at 4, 5 and 6 per cent., payable semi-annually, use the tables at 2, 2½ and 3 per cent., dividing the year numeral by 2.

The fourth column, "present value of \$1 annuity for n years," is calculated for an annuity payable at the beginning of the year. The data for an annuity payable at the end of the year by taking the next year's figure and deducting \$1 from it.

COMPOUND INTEREST AND DISCOUNT TABLES

		Three r	er cent.		Three	and one	-half per	cent.
Years	Am't of \$1 in n yrs.	Present val. of \$1 due in n yrs.	Am't of \$1 per annum in n yrs.	Present val. of \$1 annuity for n yrs.	Am't of \$1 in n yrs.	Present val. of \$1 due in n yrs.	Am't of \$1 per annum in n yrs.	Present val. of \$1 annuity for n yrs.
1 2 3 4	\$1.030 1.061 1.093	.9709 .9426 .9151	1.03 2.09 3.18	1.000 1.971 2.913	\$1.035 1.071 1.109	.9662 .9335 .9019	1.04 2.11 3.21	1.000 1.966 2.900
5	1.126 1.159	.8885 .8626	4.31 5.47	3.829 4.717	1.148	.8714 .8420	4.36 5.55	3.802 4.673
6	1.194	.8375	6.66	5.580	1.229	.8135	6.78	5.515
7	1.230	.8131	7.89	6.417	1.272	.7860	8.05	6.329
8	1.267	.7894	9.16	7.230	1.317	.7594	9.37	7.115
9	1.305	.7664	10.46	8.020	1.363	.7337	10.73	7.874
10	1.344	.7441	11.81	8.786	1.411	.7089	12.14	8.608
11	1.384	.7224	13.19	9.530	1.460	,6849	13.60	9.317
12	1.426	.7014	14.62	10.253	1.511	.6618	15.11	10.002
13	1.469	.6810	16.09	10.954	1.564	.6394	16.68	10.663
14	1.513	.6611	17.60	11.635	1.619	.6178	18.30	11.303
15	1.558	.6419	19.16	12.296	1.675	.5969	19.97	11.921
16	1.605	.6232	20.76	12.938	1.734	.5767	21.71	12.517
17	1.653	.6050	22.41	13.561	1.795	.5572	23.50	13.094
18	1.702	.5874	24.12	14.166	1.857	.5384	25.36	13.651
19	1.754	.5703	25.87	14.754	1.923	.5202	27.28	14.190
20	1.806	.5537	27.68	15.324	1.990	.5026	29.27	14.710
21	1.860	.5375	29.54	15.877	2.059	.4856	31.33	15.212
22	1.916	.5219	31.45	16.415	2.132	.4692	33.46	15.698
23	1.974	.5067	33.43	16.937	2.206	.4533	35.67	16.167
24	2.033	.4919	35.46	17.444	2.283	.4380	37.95	16.620
25	2.094	.4776	37.55	17.936	2.363	.4231	40.31	17.058
26	2.157	.4637	39.71	18.413	2.446	.4088	42.76	17.482
27	2.221	.4502	41.93	18.877	2.532	.3950	45.29	17.890
28	2.288	.4371	44.22	19.327	2.620	.3817	47.91	18.285
29	2.357	.4243	46.58	19.764	2.712	.3687	50.62	18.667
30	2.427	.4120	49.00	20.188	2.807	.3563	53.43	19.036
31	2.500	.4000	51.50	20.600	2.905	.3442	56.33	19.392
32	2.575	.3883	54.08	21.000	3.007	.3326	59.34	19.736
33	2.652	.3770	56.73	21.389	3.112	.3213	62.45	20.069
34	2.732	.3660	59.46	21.766	3.221	.3105	65.67	20.390
35	2.814	.3554	62.28	22.132	3.334	.3000	69.01	20.701
36	2.898	.3450	65.17	22.487	3.450	.2898	72.46	21.001
37	2.985	.3350	68.16	22.832	3.571	.2800	76.03	21.290
38	3.075	.3252	71.23	23.167	3.696	.2706	79.72	21.571
39	3.167	.3158	74.40	23.492	3.825	.2614	83.55	21.841
40	3.262	.3066	77.66	23.808	3.959	.2526	87.51	22.103
41	3.360	.2976	81.02	24.115	4.098	.2440	91.61	22.355
42	3.461	.2890	84.48	24.412	4.241	.2358	95.85	22.599
43.	3.565	.2805	88:05	24.701	4.390	.2278	100.24	22.835
44	3.671	.2724	91.72	24.982	4.543	.2201	104.78	23.063
45	3.782	.2644	95.50	25.254	4.702	.2127	109.48	23.283
46	3.895	.2567	99.40	25.519	4.867	.2055	114.35	23.495
47	4.012	.2493	103.41	25.775	5.037	.1985	119.39	23.701
48	4.132	.2420	107.54	26.025	5.214	.1918	124.60	23.899
49	4.256	.2350	111.80	26.267	5.396	.1853	130.00	24.091
50	4.384	.2281	116.18	26.502	5.585	.1791	135.58	24.277

COMPOUND INTEREST AND DISCOUNT TABLES

		Four p	er cent.	· · · · · · · · · · · · · · · · · · ·		Five p	er cent.	
Years	Am't of \$1 in'n yrs.	Present val. of \$1 due in n yrs.	Am't of \$1 per annum in n yrs.	Present val. of \$1 annuity for n yrs.	Am't of \$1 in n yrs.	Present val. of \$1 due in n yrs.	Am't of \$1 per annum in n yrs.	Present val. of \$1 an- nuity for n yrs.
1 2 3	\$1.040	.9615	1.04	1.000	\$1.050	.9524	1.05	1.000
	1.082	.9246	2.12	1.962	1.103	.9070	2.15	1.952
	1.125	.8890	3.25	2.886	1.158	.8638	3.31	2.859
2 3 4 5	1.170	.8548	4.42 5.63	3.775 4.630	1.216	.8227 .7835	4.53 5.80	3.723 4.546
6 7 8 9	1.265 1.316 1.369 1.423 1.480	.7903 .7599 .7307 .7026 .6756	6.90 8.21 9.58 11.01 12.49	5.452 6.242 7.002 7.733 8.435	1.340 1.407 1.477 1.551 1.629	.7462 .7107 .6768 .6446 .6139	7.14 8.55 10.03 11.58 13.21	5.329 6.076 6.786 7.463 8.108
11 12 13 14 15	1.539 1.601 1.665 1.732 1.801	.6496 .6246 .6006 .5775	14.03 15.63 17.29 19.02 20.82	9.111 9.760 10.385 10.986 11.563	1.710 1.796 1.886 1.980 2.079	.5847 .5568 .5303 .5051	14.92 16.71 18.60 20.58 22.66	8.722 9.306 9.863 10.394 10.899
16	1.873	.5339	22.70	12.118	2.183	.4581	24.84	11.380
17	1.948	.5134	24.65	12.652	2.292	.4363	27.13	11.838
18	2.026	.4936	26.67	13.166	2.407	.4155	29.54	12.274
19	2.107	.4746	28.78	13.659	2.527	.3957	32.07	12.690
20	2.191	.4564	30.97	14.134	2.653	.3769	34.72	13.085
21	2.279	.4388	33.25	14.590	2.786	.3589	37.51	13.462
22	2.370	.4220	35.62	15.029	2.925	.3419	40.43	13.821
23	2.465	.4057	38.08	15.451	3.072	.3256	43.50	14.163
24	2.563	.3901	40.65	15.857	3.225	.3101	46.73	14.489
25	2.666	.3751	43.31	16.247	3.386	.2953	50.11	14.799
26	2.772	.3607	46.08	16.622	3.556	.2812	53.67	15.094
27	2.883	.3468	48.97	16.983	3.733	.2678	57.40	15.375
28	2.999	.3335	51.97	17.330	3.920	.2551	61.32	15.643
29	3.119	.3207	55.08	17.663	4.116	.2429	65.44	15.898
30	3.243	.3083	58.33	17.984	4.322	.2314	69.76	16.141
31	3.373	.2965	61.70	18.292	4.538	.2204	74.30	16.372
32	3.508	.2851	65.21	18.588	4.765	.2099	79.06	16.593
33	3.648	.2741	68.86	18.874	5.003	.1999	84.07	16.803
34	3.794	.2636	72.65	19.148	5.253	.1904	89.32	17.003
35	3.946	.2534	76.60	19.411	5.516	.1813	94.84	17.193
36	4.104	.2437	80.70	19.665	5.792	.1727	100.63	17.374
37	4.268	.2343	84.97	19.908	6.081	.1644	106.71	17.547
38	4.439	.2253	89.41	20.143	6.385	.1566	113.10	17.711
39	4.616	.2166	94.03	20.368	6.705	.1491	119.80	17.868
40	4.801	.2083	98.83	20.584	7.040	.1420	126.84	18.017
41	4.993	.2003	103.82	20.793	7.392	.1353	134.23	18.159
42	5.193	.1926	109.01	20.993	7.762	.1288	141.99	18.294
43	5.400	.1852	114.41	21.186	8.150	.1227	150.14	18.423
44	5.617	.1781	120.03	21.371	8.557	.1169	158.70	18.546
45	5.841	.1712	125.87	21.549	8.985	.1113	167.69	18.663
46	6.075	.1646	131.95	21.720	9.434	.1060	177.12	18.774
47	6.318	.1583	138.26	21.885	9.906	.1009	187.03	18.880
48	6.571	.1522	144.83	22.043	10.401	.0961	197.43	18.981
49	6.833	.1463	151.67	22.195	10.921	.0916	208.35	19.077
50	7.107	.1407	158.77	22.341	11.467	.0872	219.82	19.169

COMPOUND INTEREST AND DISCOUNT TABLES

		Six pe	r cent.				Six per	cent.	
Years	Am't of \$1 in n yrs.	Present val. of \$1 due in n yrs.	Am't of \$1 per annum in n yrs.	Present val. of \$1 annuity for n yrs.	Years	Am't of \$1 in n yrs.	Present val. of \$1 due in n yrs.	Am't of \$1 per annum in n yrs.	Present val. of \$1 annuity for n yrs.
1 2 3 4 5	\$1.060 1.124 1.191 1.262 1.338	.8900 .8396 .7921	1.06 2.18 3.37 4.64 5.98	1.000 1.943 2.833 3.673 4.465	26 27 28 29 30	4.549 4.822 5.112 5.418 5.743	.2198 .2074 .1956 .1846 .1741	62.71 67.53 72.64 78.06 83.80	13.003 14.211 14.406
6 7 8 9 10	1.419 1.504 1.594 1.689 1.791	.6651 .6274 .5919	7.39 8.90 10.49 12.18 13.97	5.212 5.917 6.582 7.210 7.802	31 32 33 34 35	6.088 6.453 6.841 7.251 7.686	.1643 .1550 .1462 .1379 .1301	89.89 96.34 103.18 110.43 118.12	14.929 15.084 15.230
11 12 13 14 15	1.898 2.012 2.133 2.261 2.397	.4970 .4688 .4423	15.87 17.88 20.02 22.28 24.67	8.360 8.887 9.384 9.853 10.295	36 37 38 39 40	8.147 8.636 9.154 9.704 10.286	.1227 .1158 .1092 .1031 .0972	126.27 134.90 144.06 153.76 164.05	15.621 15.737 15.846
16 17 18 19 20	2.540 2.693 2.854 3.026 3.207	.3714 .3503 .3305	27.21 29.91 32.76 35.79 38.99	10.712 11.106 11.477 11.828 12.158	41 42 43 44 45	10.903 11.557 12.250 12.985 13.765	.0917 .0865 .0816 .0770 .0727	174.95 186.51 198.76 211.74 225.51	16.138 16.225 16.306
21 22 23 24 25	3.400 3.604 3.820 4.049 4.292	.2775 .2618 .2470	42.39 46.00 49.82 53.86 58.16	12.470 12.764 13.042 13.303 13.550	46 47 48 49 50	14.590 15.466 16.394 17.378 18.420	.0685 .0647 .0610 .0575 .0543	240.10 255.56 271.96 289.34 307.76	16.524 16.589 16.650

These tables are an abridgement of the seven-place tables in "Annuaire pour l'an 1913," published for the Bureau of Longitudes, by Gauthier-Villars, Quai des Grands-Augustins, 55; Paris, France.

Bond Interest.—The true return on a bond is not the interest rate divided by the purchase price, for if the bond be paid at par at maturity, the discount is earned if the bond was purchased below par. while if it was purchased above par, the premium must be amortized. If P is the price of a bond with n years to run; S the face of the bond, q the rate of interest current (expressed as a decimal); r the stipulated rate of the bond (as a decimal, .05, .06); x the interest on the investment,

for annual payments
$$1 + x = \left[\frac{S\{(q-r) + r(1+q)^n\}}{Pq}\right]^{1/n}$$
for semiannual payments $1 + x = \left[\frac{S\{(q-r) + r(1+q)^n\}}{Pq}\right]^{1/n}$

ANNUAL INVESTMENT TABLE¹
The sum of money which must be invested at the beginning of each year for a period of 1 to 50 years to amount to \$1000 at compound interest.

Years	2 Per cent.	3 Per cent.	3½ Per cent.	4 Per cent.	5 Per cent.	6 Per cent.	Years
1	\$980.39	970.87	966.18	961.55	952.38	943.39	1
2	485.43	478.24	474.83	471.25	464.47	457.88	2
3	320.31	314.07	311.04	307.98	302.11	296.30	3
4	237.87	232.07	229.20	226.45	220.95	215.66	4
5	188.40	182.88	180.18	177.53	172.35	167.36	5
6	155.42	150.08	147.51	144.97	140.02	135.24	6
7	131.87	126.71	124.19	121.74	116.97	112.39	7
8	114.22	109.18	106.74	104.35	99.73	95.32	8
9	100.50	95.57	93.19	90.86	86.37	82.10	9
10	89.53	84.69	. 82.36	80.09	75.72	71.57	10
11	80.57	75.80	73.52	71.30	67.04	63.01	11
12	73.10	68.41	66.17	63.99	59.83	55.92	12
13	66.78	62.17	59.96	57.83	53.77	49.96	13
14	61:38	56.82	54.66	52.57	48.59	44.89	14
15	56.69	52.20	50.07	48.02	44.14	40.53	15
16	52.60	48.16	46.07	44.06	40.26	36.75	16
17	48.99	44.61	42.55	40.58	36.86	33.44	17
18	45.79	41.46	39.44	37.49	33.85	30.53	18
19	42.92	38.65	36.66	34.75	31.19	27.94	19
20	40.35	36.13	34.17	32.29	28.80	25.65	20
21	38.02	33.86	31.92	30.08	26.66	23.59	21
22	35.91	31.79	29.89	28.08	24.73	21.74	22
23	33.99	29.92	28.04	26.26	22.99	20.07	23
24	32.23	28.20	26.35	24.60	21.40	18.57	24
25	30.61	26.63	24.81	23.09	19.95	17.20	25
26	29.12	25.18	23.39	21.70	18.63	15.95	26
27	27.74	23.85	22.08	20.42	17.42	14.81	27
28	26.46	22.61	20.87	19.24	16.31	13.77	28
29	25.27	21.47	19.75	18.15	15.28	12.81	29
30	24.17	20.41	18.72	17.14	14.33	11.93	30
31	23.13	19.42	17.75	16.21	13.46	11.12	31
32	22.17	18.49	16.85	15.34	12.65	10.38	32
33	21.26	17.63	16.01	14.52	11.90	9.69	33
84	20.41	16.82	15.23	13.76	11.20	9.06	34
35	19.61	16.06	14.49	13.06	10.54	8.47	35
36	18.86	15.34	13.80	12.39	9.94	7.92	36
37	18.14	14.67	13.15	11.77	9.37	7.41	37
38	17.47	14.04	12.54	11.18	8.84	6.94	38
39	16.83	13.44	11.97	10.64	8.35	6.50	39
40	16.23	12.88	11.43	10.12	7.88	6.10	40
41	15.66	12.34	10.92	9.63	7.45	5.72	41
42	15.11	11.84	10.43	9.17	7.04	5.36	42
43	14.60	11.36	9.98	8.74	6.66	5.03	43
44	14.11	10.90	9.54	8.33	6.30	4.72	44
45	13.64	10.47	9.13	7.94	5.97	4.43	45
46	13.20	10.06	8.74	7.57	5.64	4.16	46
47	12.78	9.66	8.37	7.23	5.34	3.91	47
48	12.37	9.29	8.02	6.90	5.06	3.67	48
49	11.97	8.94	7.69	6.59	4.79	3.45	49
50	11.60	8.61	7.37	6.29	4.55	3.25	50

¹ From "Lefax," Philadelphia, Penn.

AMORTIZATION AND DEPRECIATION FORMULAS¹

Amount of an annuity which at the end of n years will amortize a capital of \$1 (interest on annuity payments and on original capital figured at the same rate).

Annuity =
$$\frac{r(1+r)^n}{(1+r)^n-1}$$
.\$1

Present value of an annuity of \$1 per year, payable for nyears, at the end of the year.

Present value =
$$\frac{1}{r} \left[1 - \frac{1}{(1+r)^n} \right] \cdot \$1$$

The sum produced at the end of n years by placing annually \$1 at r interest, each dollar being deposited at the beginning of the year.

Sum =
$$\frac{1+r}{r}[(1+r)^n-1]\cdot\$1$$

Present worth of \$1 payable at the end of n years.

Present worth =
$$\frac{\$1}{(1+r)^n}$$

Value at the end of n years of \$1 at compound interest. Value = $(1 + r)^n \cdot \$1$

AREAS

Triangle = base × ½ altitude

Triangle (let a, b, and c be the sides and 2s = a + b + c)

Area =
$$\sqrt{s(s-a)(s-b)(s-c)}$$

Trapezoid = $\frac{1}{2}$ sum of the bases \times the altitude

 $Circle = \pi r^2$

Sphere = $4\pi r^2 = \pi d^2$

Cylinder (total surface) = $2\pi r^2 + 2\pi rh$ (h = height or altitude) Cylinder (cylindrical surface only) = $\pi dh = 2\pi rh$

Cone = $\pi r^2 + 2\pi r (\frac{1}{2} \sqrt{r^2 + h^2})$

Regular polygons—where side = s, or r = apothem (radius of inscribed circle)

 $1.7204778^2 = 3.63271r^2$ 5 sides (pentagon)

 $2.598076s^2 = 3.46410r^2$

6 sides (hexagon)
7 sides (heptagon)
8 sides (octagon)
9 sides (nonagon) $3.633912s^2 = 3.37101r^2$

 $4.8284278^2 = 3.31371r^2$

 $6.181824s^2 = 3.27573r^2$

10 sides (decagon) $7.694209s^2 = 3.24920r^2$

11 sides (undecagon) $9.365640s^2 = 3.22993r^2$

12 sides (duodecagon) 11.196152 $s^2 = 3.21539r^2$

for
$$n$$
 sides, $A = \frac{n}{4}s^2 \cot \frac{180^{\circ}}{n} = nr^2 \tan \frac{180^{\circ}}{n}$

¹ From "Annuaire pour 1915, Bureau des Longitudes." See p. 23 for bond interest formula.

TABLE OF REGULAR POLYGONS

	Name of	A	cir	ius of cum- d circle	inscrib- side	f side, circum.		Angle
No. of sides	Name of polygon	Area side $= S$ $A = cS^2$	Perp. from center = 1	Side = 1	Radius of ed circle,	Length of radius of circle = 1	Angle at center	between adjacent
3 4 5 6 7 8 9 10 11 12	Triangle Square Pentagon Hexagon Octagon Nonagon Undecagon Duodecagon.	0.4330127 1.0000000 1.7204774 2.5980762 3.6339124 4.8284271 6.1818242 7.6942088 9.3656399 11.1961524	1.414 1.238 1.115 1.110 1.083 1.064 1.051	0.7071 0.8506 1.0000 1.1524 1.3066 1.4619 1.6180	0.5000 0.6882 0.8660 1.0383 1.2071 1.3737 1.5388 1.7028	1.4142 1.1756 1.0000 0.8677 0.7653 0.6840 0.6180 0.5634	90° 72° 60° 51°26′ 45° 40° 26° 32°43′	60° 90° 108° 120° 128°34' 135° 140° 144° 147°16'21" 150°

Table of the Regular Polyhedrons whose Edge is Unity

	No. of faces	Surface ¹	Volume ²
Tetrahedron ³	4	1.7320508	0.1178513
Hexahedron (cube) ³		6.0000000	1.0000000
Octahedron ³		3.4641016	0.4717045
Dodecahedron ³		20.6457288	7.6631189
Icosahedron ⁸		8.6602540	2.1816950

¹ If the edge is not unity, multiply the constant in the table by the square of the side.

² If the edge is not unity, multiply the constant in the table by the cube of

The faces of the tetrahedron, octahedron and icosahedron (20 faces) are triangles; of the hexahedron, squares; and of the dodecahedron, pentagons.

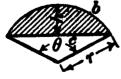


Circular Ring.—Area = $\pi (R^2 - r^2) = \pi (R - r)$ (R + r) = difference in areas between the inner and outer circles.



Quadrant.—Area = $\frac{\pi r^2}{4}$ = 0.7854 r^2 = 0.3927 c^2 . (c = chord.)

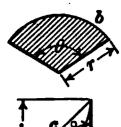
Segment.—b = length of arc. θ = angle in degrees. $c = \text{chord} = \sqrt{4(2hr - h^2)}$

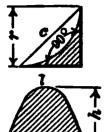


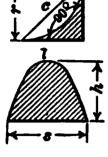
From
$$= \sqrt{4(2hr - h^2)}$$

Area $= \frac{1}{2}[br - c(r - h)]$
 $= \pi r^2 \frac{\theta}{360} - \frac{c(r - h)}{2}$

When θ is greater than 180°, then $\frac{c}{2} \times \text{difference}$ between r and h is added to the fraction $\frac{\pi r^2 \theta}{360}$.







Sector.—Area =
$$\frac{1}{2}br = \pi r^2 \frac{\theta}{360^\circ}$$

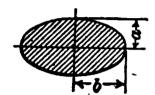
 θ = angle in degrees b = length of arc

Spandrel.—Area = $0.2146r^2$ = $0.1073c^2$ Parabola.—Area = $\frac{2}{3}8h$

$$l = \text{length of curved line} = \text{periphery} - s = \frac{s^2}{8h}$$

 $(\sqrt{c(1+c} + 2.0326 \times \log (\sqrt{c} + \sqrt{1+c})))$

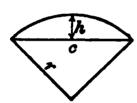
where $c = \left(\frac{4h}{s}\right)^2$



Ellipse.—Area = πab

Circum. =
$$\pi(a + b) \frac{64 - 3 \left(\frac{b - a}{b + a}\right)^4}{64 - 16\left(\frac{b - a}{b + a}\right)^2}$$

[close approximation]



Sector of Sphere.—Total surface = $\frac{\pi r}{2}(4h + c)$;

$$c = 2\sqrt{(2hr - h^2)}$$
.
Volume $= \frac{2\pi r^2 h}{3} = \frac{2\pi r^2}{3} \left(r - \frac{\sqrt{4r^2 - c^2}}{2}\right)$

Segment of Sphere.—Spherical surface

$$= 2\pi rh = \frac{\pi}{4}(c^2 + 4h^2)$$

 $=2\pi rh + \frac{\pi}{4}c^2 = \frac{\pi}{2}(c^2 + 2h^2)$ Total surface

Volume
$$= \pi h^2 \left(r - \frac{h}{3} \right) = \pi h^2 \left(\frac{c^2 + 4h^2}{8h} - \frac{h}{3} \right)$$

 $c = 2\sqrt{2hr - h^2}$

Frustrum of Pyramid.—(Area of top and bottom, a and a' respectively).

Volume =
$$\frac{h}{3}(a + a' + \sqrt{aa'})$$

Ellipsoid of Revolution.—Volume = $\frac{4\pi}{3}$ (product of the three radii).

Paraboloid of Revolution.—Volume = $\frac{\pi r^2 h}{2}$.

Curved surface
$$=\frac{\pi}{6}\frac{r}{h^2}[(r^2+4h^2)^{\frac{3}{2}}-r^3]$$

Volumes

Cylinder =
$$\pi r^2 h = \frac{\pi}{4} d^2 h$$

Sphere = $\frac{\pi d^3}{6} = \frac{4}{3} \pi r^3$
Cone = $\frac{1}{3} \pi r^2 h$ ($\frac{1}{3}$ the vol. of the containing cylinder)
Pyramid = $\frac{1}{3}$ base × altitude

TRIGONOMETRY

The following formulas refer to Fig. 1.

$$\sin A = \frac{a}{c}$$

$$\cos A = \frac{b}{c}$$

$$\tan A = \frac{a}{b}$$

$$\cot A = \frac{b}{a}$$

$$\sec A = \frac{c}{b}$$

$$\csc A = \frac{c}{a}$$

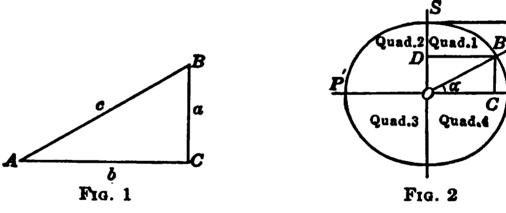
$$\cot A = \frac{b}{a}$$

$$\cot A = \frac{b}{a}$$

$$\cot A = \frac{b}{a}$$

$$\cot A = \frac{c}{a}$$

suvers
$$A = 1 + \frac{b}{c}$$



Regarding the trigonometric functions as functions of the arc, rather than of the angle (see Fig. 2) we have:

$$\sin \alpha = BC = OD$$
 $\cot \alpha = RS$
 $\cos \alpha = OC = BD$ $\sec \alpha = OQ$
 $\tan \alpha = PQ$ $\csc \alpha = OR$
 $\operatorname{vers} \alpha = CP$ $\operatorname{covers} \alpha = SD$

suvers $\alpha = P'C$

The fundamental trigonometric formulæ are:

$$\frac{1}{\cos \sec \alpha} = \sqrt{1 - \cos^2 \alpha} = \frac{\tan \alpha}{\sqrt{1 + \tan^2 \alpha}} = \frac{1}{\sqrt{1 + \cot^2 \alpha}} = \frac{\sqrt{\sec^2 \alpha - 1}}{\sec \alpha}$$

$$\cos \alpha = \frac{1}{\sec \alpha} = \sqrt{1 - \sin^2 \alpha} = \frac{1}{\sqrt{1 + \tan^2 \alpha}} = \frac{\cot \alpha}{\sqrt{1 + \cot^2 \alpha}} = \frac{\sqrt{\csc^2 \alpha - 1}}{\csc \alpha}$$

$$\tan \alpha = \frac{1}{\cot \alpha} = \frac{\sin \alpha}{\sqrt{1 - \sin^2 \alpha}} = \frac{\sqrt{1 - \cos^2 \alpha}}{\cos \alpha} = \sqrt{\sec^2 \alpha - 1} = \frac{1}{\sqrt{\csc^2 \alpha - 1}}$$

$$\frac{1}{\operatorname{ant} \alpha} = \frac{\sqrt{1-\sin^2 \alpha}}{\sin \alpha} = \frac{\cos}{\sqrt{1-\cos^2 \alpha}} = \frac{1}{\sqrt{\sec^2 \alpha + 1}} = \sqrt{\csc^2 \alpha - 1}$$

$$\sec \alpha = \frac{1}{\cos \alpha} = \frac{1}{\sqrt{1-\sin^2 \alpha}} = \sqrt{1+\tan^2 \alpha} = \frac{\sqrt{1+\cot^2 \alpha}}{\cot \alpha} = \frac{\csc \alpha}{\sqrt{\csc^2 \alpha - 1}}$$

$$\csc \alpha = \frac{1}{\sin \alpha} = \frac{1}{\sqrt{1-\cos^2 \alpha}} = \frac{\sqrt{1+\tan^2 \alpha}}{\tan \alpha} = \sqrt{1+\cot^2 \alpha} = \frac{\sec \alpha}{\sqrt{\sec^2 \alpha - 1}}$$

$$\sin^2 \alpha + \cos^2 \alpha = 1; \tan \alpha = \frac{\sin \alpha}{\cos \alpha}; \cot \alpha = \frac{\cos \alpha}{\sin \alpha}$$

Rule for signs of trigonometric functions in various quadrants:

	Quadrant	1	2	3	4
sin	•	+	+	_	-
COS		+	<u>سید</u>		+
tan cot		+		+	-
cot		+	_	+	-
Bec		+	- ·	_	+
cosec		+	+		_

Any function of 0° or an even multiple of 90°, $\left(\frac{\pi}{2}\right)$, plus or minus A, is the same function of A, and any function of an odd multiple of 90° is the complementary function of A, the sign being determined for the appropriate quadrant by the above table.

above table.
$$\sin(x + y) = \sin x \cos y + \cos x \sin y \therefore \sin 2x = 2 \sin x \cos x \cos x \cos y - \sin x \sin y \therefore \cos 2x = \cos^2 x - \sin^2 x \sin (x - y) = \cos x \cos y - \cos x \sin y = \cos x \cos y + \sin x \sin y$$

$$\tan(x - y) = \frac{\tan x + \tan y}{1 - \tan x \tan y}$$

$$\tan(x - y) = \frac{\tan x - \tan y}{1 + \tan x \tan y}$$

$$\cot(x + y) = \frac{\cot x \cot y - 1}{\cot y + \cot x}$$

$$\cot(x - y) = \frac{\cot x \cot y - 1}{\cot y - \cot x}$$

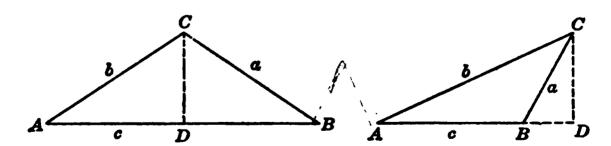
$$\frac{\sin(x + y)}{\sin(x - y)} = \frac{\tan x + \tan y}{\tan x - \tan y}$$

$$\frac{\cos(x + y)}{\cos(x - y)} = \frac{1 - \tan x \tan y}{1 + \tan x \tan y}$$

$$\frac{\sin (x + y)}{\cos (x - y)} = \frac{\tan x + \tan y}{1 + \tan x \tan y} \\
\frac{\sin (x - y)}{\cos (x + y)} = \frac{\tan x - \tan y}{1 - \tan x \tan y} \\
\sin (x + y) \sin (x - y) = \sin^2 x - \sin^2 y = \cos^2 y - \cos^2 x \\
\cos (x + y) \cos (x - y) = \cos^2 x - \sin^2 y^2 = \cos^2 y - \sin^2 x \\
\sin 2x = 2 \sin x \cos x \\
\cos 2x = \cos^2 x - \sin^2 x = 2 \cos^2 x - 1 = 1 - 2 \sin^2 x \\
\tan 2x = \frac{2 \tan x}{1 - \tan^2 x} \\
\cot 2x = \frac{\cot^2 x - 1}{2 \cot x} \\
\sin \frac{1}{2}x = \sqrt{\frac{1 - \cos x}{2}} \\
\cos \frac{1}{2}x = \frac{\sin x}{1 + \cos x} \\
\cot \frac{1}{2}x = \frac{\sin x}{1 - \cos x} \\
\cot \frac{1}{2}x = \frac{\sin x}{1 - \cos x} \\
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\cot \frac{1}{2}x = \frac{1}{2}x =$$

Solution of Triangles,

The solution of the right triangle is readily deduced from the functional equations applying to Fig. 1.



The solution of oblique triangles is given in the following formula:

$$\frac{a+b}{a-b} = \frac{\sin A + \sin B}{\sin A - \sin B} = \frac{\tan \frac{1}{2}(A+B)}{\tan \frac{1}{2}(A-B)} = \frac{\cot \frac{1}{2}C}{\tan \frac{1}{2}(A-B)}$$

$$a^{2} = b^{2} + c^{2} - 2bc \cos A \text{ or } c^{2} = a^{2} + b^{2} - 2ac \cos C$$

$$\cos A = \frac{b^{2} + c^{2} - a^{2}}{2bc} \text{ or } \cos C = \frac{a^{2} + b^{2} - c^{2}}{2ab}$$

$$\sin \frac{1}{2}A = \sqrt{\frac{(a+b-c)(a-b+c)}{4bc}} = \sqrt{\frac{(s-a)(s-b)}{bc}}$$

$$\cos \frac{1}{2}A = \sqrt{\frac{s(s-a)}{bc}}$$

$$\tan \frac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{bc}} \sqrt{\frac{bc}{s(s-a)}}$$

$$\sin A = 2\sqrt{\frac{(s-b)(s-c)}{bc}} \sqrt{\frac{s(s-a)}{bc}}$$

$$Area = \frac{ab \sin C}{2} = \frac{bc \sin A}{2} = \frac{ac \sin B}{2} = \frac{b^2 \sin C \sin A}{2 \sin B} = \sqrt{s(s-a)(s-b)(s-c)}$$

Radius of inscribed circle = $\frac{\text{area}}{\frac{1}{2} \text{ perimeter}}$

Radius of circumscribed circle = $\frac{\text{(product of the sides)}}{\text{(four times area)}}$

EXACT NUMERICAL VALUE OF THE FUNCTIONS OF SOME ANGLES

Angle	0°	30°	45°	60°	90°	120°	135°	150°	180°	270°	360°
Sine	0	36	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	34	0	-1	0
Cosine	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	34	0	- 3/2	$-\frac{1}{\sqrt{2}}$	$-\frac{\sqrt{3}}{2}$	-1	0	1
Tangent	0	$\frac{1}{\sqrt{3}}$	1	$\sqrt{3}$	8	$-\sqrt{3}$	-1	$-\frac{1}{\sqrt{3}}$	0	o	0
Cotangent	8	$\sqrt{3}$	1	$\frac{1}{\sqrt{3}}$	0	$-\frac{1}{\sqrt{3}}$	-1	$-\sqrt{3}$	8	0	œ
Secant	1	$\frac{2}{\sqrt{3}}$	$\sqrt{2}$	2	&	-2	$-\sqrt{2}$	$-\frac{2}{\sqrt{3}}$	-1	o	1
Cosecant	8	2	$\sqrt{2}$	$\frac{2}{\sqrt{3}}$	1	$\frac{2}{\sqrt{3}}$	$\sqrt{2}$	2	8	-1	80
Versed sine	0	$\frac{2-\sqrt{3}}{2}$	$\frac{\sqrt{2}-1}{2}$	3/2	1	34	$\frac{1+\sqrt{2}}{\sqrt{2}}$	$\frac{2+\sqrt{3}}{2}$	2	1	0
Covers. sine	1	1/2	$\frac{\sqrt{2}-1}{\sqrt{2}}$	$\frac{2-\sqrt{3}}{2}$	0	$\frac{2-\sqrt{3}}{2}$	$\frac{\sqrt{2}-1}{\sqrt{2}}$	34	1	2	1

SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS FROM 1 TO 1000

_					4:				
No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
1 8 3 4 500 7 8 9 0	1 4 9 16 25 36 49 64 81 100	27 64 125 216 343 512 729	1.0000 1.4142 1.7321 2.0000 2.2361 2.4495 2.6458 2.8284 3.0000 3.1623	1.0000 1.2599 1.4422 1.5874 1.7100 1.8171 1.9129 2.0000 2.0801 2.1544	51 52 53 54 55 50 57 58 59 60	2601 2704 2809 2916 3025 3136 3249 3364 3481 3600	132651 140608 148877 157464 106375 175616 185193 195112 205379 216000	7 1414 7.2111 7.2801 7.3485 7.4162 7.4833 7.5498 7.6158 7.6811 7.7460	3.8030 3.8239 3.8485 3.8709 3.8930
11 12 13 14 15 10 17 18 19	121 144 160 196 225 250 289 324 361 400	1331 1728 2107 2744 3375 4096 4913 5832 0850 8000	3.3166 3.4641 3.6056 3.7417 3.8730 4.0000 4.1231 4.2426 4.3589 4.4721	2.2240 2.2894 2.3513 2.4101 2.4662 2.5198 2.5713 2.6207 2.6684 2.7144	61 62 63 64 65 66 67 68 69 70	3721 3844 3909 4096 4225 4350 4489 4624 4761 4900	226981 238328 250047 262144 274625 287496 300763 314432 328509 343009	7.8102 7.8740 7.9373 8.0000 8.0023 8.1240 8.1854 8.2462 8.3066 8.3666	3-9579 3-9791 4-0000 4-0207 4-0412 4-0615 4-0817 4-1010
21 22 23 24 25 20 27 28 29 30	44E 484 529 576 625 670 729 784 841 900	9261 10648 12167 13824 15625 17576 19683 21952 24389 27000	4-5826 4-5904 4-7958 4-8990 5-0000 5-0990 5-1962 5-2915 5-3852 5-4772	2.7589 2.8020 2.8439 2.8845 2.9240 2.9625 3.0000 3.0366 3.0723 3.1072	71 73 73 74 75 76 77 78 79 80	\$041 5184 5329 5476 5625 5776 5929 6084 6241 6400	357911 373248 389017 405224 421875 438970 456533 474552 493939 512000	8.4261 8.4853 8.5440 8.6603 8.7178 8.7750 8.8318 8.8882 8.9443	4.1602
31 32 33 34 35 36 37 38 39	961 1024 1089 1156 1225 1206 1369 1444 1521 1600	29791 32768 35937 39304 42875 46656 50653 54872 59319 64000	5.3678 5.6569 5.7446 5.8310 5.0161 6.0000 6.0828 6.1644 6.2450 6.3246	3.1414 3.1748 3.2075 3.2396 3.2711 3.3019 3.3322 3.3020 3.3012	8x 82 83 84 85 86 87 88	6561 6724 6889 7056 7225 7396 7569 7744 7921 8100	531441 551368 571787 592704 614125 630056 658503 681472 704969 729000	9,0000 9,0554 9,1104 9,1052 9,2195 9,2736 9,3808 9,4340 9,4868	4-3445 4-3021 4-3705 4-3968 4-4140 4-4319 4-4480
41 42 43 44 45 46 47 48 49 50	1681 1764 1840 1936 2025 2116 2209 2304 2401 2500	68921 74088 79507 85184 91125 97336 103823 110592 117640 125000	6.4031 6.4807 6.5574 6.6332 6.7082 6.7823 6.8557 6.9282 7.0000 7.0711	3.4482 3.4760 3.5034 3.5303 3.5569 3.5830 3.6840 3.6840	91 92 93 94 95 96 97 98 99	8281 8464 8640 8836 9025 9216 9400 9604 9801 10000	753571 778688 804357 830584 857375 884730 912673 941192 970299 1000000	9.5394 9.59x7 9.6437 9.6954 9.7468 9.7980 9.8489 9.8995 9.8995	4.5144 4.5307 4.5468 4.5020

MATHEMATICS

SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS FROM 1 TO 1000

No.	Square	Cube	Sq. Root	Cube Root	No	Square	Cube	Sq Root	Cube Root
101	10301	1030301	10.0400	4 6570	1,51	22801	3442051	12 2882	5 1251
101,	10404	1001308	10.0005	4.6723	152	23104	3511808	12 5288	5 1368
103	10000	1092727	10 1489	4.6875	153	23400	1581577	13 3693	5 3485
304	10816	1157615	10 1980	4.7027	154	24075	3652264	12 4097, 12 4400	5 360E
105	11236	\$101010	10.2050	4.7320	150.	- 7	3796416	12 4000	5 1717
107	11440	1775045	10.3441	4 7475	157	24649	3800803	12 5100	5 1947
108	11004	1259712	10.3023	4 7622	: 58	24964	3944312	12 5698	5 4001
TOO	11881	1302030	10.4403	4-7700	150		4010070	13 0003	5 4175
IIO	11100	1331000	10.4581	4.7914	100	25000	4090000	12 6491	\$4288
111	12321	1367631	10.5357	4.8059	161	25921	4173281	r= 6886	5. 440I
123	12544	1404938	10.5830	4 8203	103	20144	4251518	12 7279	5 4514
113	12769	1442807	10.6301	4.8346	163	26560	4339747	11 7671	5 4636
214	£2990	1481544	10 0771	4 8488 4 8629	104	26806	4410044	12 8062	5 4737
IIS	13450	1520875	10 7138	4 8770	166	27275	4402125	12 8452 12 8841	5 4845
317	13689	1001013	10.8167	4.8010	167	21830	4657463	12 9228	5 500Q
811	13014	1643032	10 8618	4 9049	168	28224	4741632	12 9615	5 5178
110	14161	2685150	10.0087	4.9187	160	28561	4826800	13.0000	5 5388
130	14400	1728000	10.9545	4 9324	170	18000	4913000	13.0384	5-5397
121	24541	2771561	\$1.0000	4.0461	271	20241	5000211	13.0767	5 5505
222	14864	1815848	11.0454	4 9597	372	20584	5088448	13 1140	5 5613
133	15120	1860867	££ 0005	4.9732	173	20020	5177717	13 1529	5 5722
	15376	1006624	11 1155	4 9866	574	302,6	5268024	11 1000	5 5828
125	15876	2000376	11 1805	5 0000	276	30025	5350475 5451770	13 2288	5 5034
127	10120	2048383	11 1004	20102	177	11 120	5545233	13.3041	5 6147
128	16384	2007152	11 3137	5.0307	178	31684	5610752	13 3417	5 6252
130	16641	2140689	11 357B	5.0528	179	3204L	5735330	11 3701,	\$ 6157
130	Eggoo	2197900	11 4018	\$.0058	190	32400	5832000	13.4164	5.6462
IJI	27161	2248001	11 4455	5 0788	181	32761	5070741	13 4536	5 6567
132	27424	2200908	11 4801	5 0010	182	33134	0028568	13 4907	5 6671
133	17689	2353617	11 4326	5 1045	181	33489 33856	6128487	13 5277	5 6774
134 135	18115	2400104 2400375	11 5758	5 1200	185	34925	6331645	13 5047	5 6080
130	18400	2515456	C100 16	5 1416	180	14100	64 54856	1; 6;82	5 7083
137	18760	2571353	11 7047]	5 1550	187	11000	6539203	13 6748	5 7185
138	19044	2028012	17 7473	5 1676	188,	35144	0044074	13 7113	5 7 187
139 140	19321	#685619 #744000	11 7898	5 1801 5.1925	180	35721	6751269 6850000	13 7477	5.7388 5.7489
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143 143	20104	20032001	11 0583	5 2171	192	37149	7180057	1 3 8024	5 7790
244	20736	2085084	12 0000	5 7415	Ivi	37030	7301384	13.9284	5 7890
145	21025	3048625	12 0416	\$ 2536	195	35025	7414875	11 0012	5 7989
146	21316	3112136	12.0830	5 2656	Lúb	15416	7520536	14 0000	5 Ao88
147	21009	3170523	12 1244	5 2776	197	1880g	7045373	14 0357	5 8186
145		3141707	12 1655	5 2800	tus	39204	7763393 7880500	14.0712	5 8 2 8 5
1 40 1 30	10511	3307040	12 2000	5 3015	100	39601 40000	8000000	14 1421	5 8383 5 8480
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34 METALLURGISTS AND CHEMISTS' HANDBOOK

SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS FROM

ła.	Square	Cube	Root.	Root	No.	Square	Cube	Sq. Root	Root
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01	10401	8120001	14 1774	5 8578	351	07001	52813325	15.8410	6.30
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04	41616	8480664	14 3930	< 8868	254	61210	16457004	15 9374	0 333
05	42025	8011111	14 4178	2 NO01	255	62052	104811-4	15 9087	
oó]	47430	8741515,	14 3527	5 1040	250	6.536	10-77210	10,0000	
07	42K40	8869743	14 3879,	5 4155	257	phone	16974593	10 0412	0 157
08	43204	8998912	14 4223	2 0520	1 2 18	00.564	17174513	10 0024	0 360
00	43681	9129329	14.4568,	5 9345	239	180-9	17371070	16 0935	6.374
10	44100	9201000	14 4914	2 9439	160	67000	17575000	10.1245	6.381
12	44571	9393931	14 5258[5 9533	261	69121	37770581	26 2555	6 300
12	44944	9528128	14 5003	5.0027	202	68644	17084728	16.1864	6 308
13	45560	066340*	14 5045	5 47 21	100	60150	18101447	15 2171	0 407
iii	45790	uS00 (41	11 0287	\$ 0814	201	bubah	TX100*44	10 2481	0.415
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iá!	47524	10300112	14 7644	6 0144	268	71824	19.48812	10 1207	6 147
ial	4796t	20503450	14 7986	Ó 9277	100	72361	10495100	16 4012	0 455
20	48400	10048000	14 8524	6.0368	170	74900	00068001	16.4117	0 403
	.00	vnvn - 9.6 - 1	14 866t	5 0410	111	Brest	10002511	16 4621	6 471
111	48841	1079 (861			371	71441	3013/048	10 4024	
12	40784	10041048	14 9007	6 0550	1774	71084			0 479
73	49719	11080507	14 0334	1190.0	373	24620	20345417	16 522	6-487
14;	50170	11140111	La yhôn	6 0733	2.4	7.010	20570N24	16 5510	6 105
75	20012	11.00025	1 < 0000 U	6 0822	2.6	25025	20100814	2 0132	0 503
tô.	51070	112711.0	150331	(0011		,	320344.4		5 410
7.7	51520	#16076N	15 0005	6 to02	227	7 779	2125 911	27 043	6.518
18	51034	2 ERS 3 1 5 3	15 0007	1001	274	77255	21454952	10 0743	6 526
N)	52441	£ 2005939	12 131	0 1150	279	77×41	217170391	10,013	6 534
10	\$2900	11107000	15 1055	0011.0	280	78400	21952000	10.7332	6 542
1	53361	12326301	15 1987	6 1358	281	78961	22158041	16 7631	6.540
13	53824	12487108	15 2115	Ó 1,40	282	1 3120	23424768	10 '013	6 557
13	54350	3 *649 117	15 /943	6 1534	-43	3005y	24 4 4181	TO 5130	F 405
14.	54-56	11512004	15 2972	0 1622	294	Sof 50	27000304	10.3021	0 573
15	55225	13977875	1 > 320"	6 1710	28.5	81.75	2 (149125)	10 8819	0.480
16	\$50QÓ	2 (1 44 SF	15 1625	b 1 107	346	SET N	3 11.56	I' GIIS	6.588
171	56100		15 1 H	0 (585	250	52 140	1 7 30003	1 9411	6 596
8	5D044	\$ \$476.27.2	15 42, 2	6 1074	. 4.4	87044	2 434 457	15 9700	0 603
10	571.15	11051010	15 4590	8206 0	250	815.1	2413"500]	17 0000	6 611
ю	57600	13814000	15 4919	0.2145	290	84100	2438g000	17 0294	0.010
12	shoëz	13007521	15 5343	6.2231	301	8468;	246421 1	170587	6 6 2 6
	58504	11172488	15 5501	0.1417	202	Rephy	2,140-088	E" 0850	0.054
12		14115007	25 5585	6 2403	243	3,310	251 1 5	1 1177	6 641
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넴	505 10	14789135		0.2513		3-3-5	2 41	1, 1736	1. 656
65	600.5		3 (< 3 5		205	5 010	ata and	17 2047	6 664
10	01700	01 QONN41	14 0844	0 2045	4 /0		243717	1 30	6 671
47	01000	12000333	35 -102	6 2 13	297	53 100			
68	Posto	145413001	17, 14,40	6.3.8	298	45501	27471524	1, 303,	6 579
	62001	12474510	15 37V	0.2012	2 7/3	59171	3, 47,000	13.3719	6.694
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SQUARES, CORES, SQUARE AND COME ROOMS OF NOMINERS PROME

		-	=	1				
No. Square	Cula	Sq.	Cubo Rest	No	Square	Cube	Sq. Root	Crito Beet
300 03650 300 03650 300 03650 307 04640 309 03486 309 03486 309 03486	ersagioù ereister eloquela elereis elereis elereis elereis	17-4196 17-4043 17-4010 17-3114 17-5400 17-1714	6.7387 6.7460	351 353 354 355 357 357 357 350 300	Fagent 1.2004 104600 1.25310 1.25003 1.25004 1.2604 1.2604 1.2604	43 143 \$51 436 £4568 436 £667 447 \$61 \$64 447 \$60 \$5 451 £666 4540 \$60 \$72 45 £65 \$70 456 \$70 456 \$70 456 \$70 456 \$70	18.944 18.9499 18.9473	7.0007 7.0074 7.0040 7.0007 7.0073 7.0040 7.1008
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200 200004 200 200004 201 204,30 201 204,30 201 204,30 201 204,30 201 204,30 201 204,30 201 204,30 201 204,30 201 204,30 201 204,30	\$3,500645 3,50,6367 340,61854 34,146135 34645976 34665763 25,167554 25,167554	17 9799 18 mom 18 mrs 18 mrs 18 mrs 18 mrs 18 mrs 18 mrs 18 mrs	332038	371 370 373 374 373 376 377 376 370 380	137611 138364 2381 m 138076 140561 141376 241376 141864 141864 1486410	\$1064821 \$1476648 \$1895117 \$1313644 \$1744375 \$1157576 \$157576 \$16461510 \$4617510 \$4675000	29.1624 19.1673 19.3132 19.1301 19.3007 19.4152 19.4474 19.4079 19.4039	7 2000 7 1954 7 1054 7 1123 7 1127 7 1240 7 1304 7 1466
331 100981 330 110034 334 111590 334 111590 335 113700 337 113700 338 11401 339 11401		18. 2009 18. 1483 18. 1757 18. 3030 16. 3303 16. 3570 18. 3648 18.4100	6 9131 0 9189 6 9058 6-97 17	181 183 184 185 186 180 180	145104 147490 147490 147490 148101 148100 149100 151311 252300	53305342 5374065 9518280 9518280 576633104 5766635 5796363 5796363 5796363 5796363 5796363 5796363	10.5723 10.0017 16.7232	7 a458 7 2500 7 2500 7 2748 7 2513 7 2574 7 2050
341 11682 341 11696 344 11704 344 11833 345 11902 347 18260 347 18260 348 12264 348 12360	######################################	18.4019 18.5003 18.5473 18.473 18.6011 18.6079 18.6568 18.4815	6-0032 7-0000 7-0008 7-0136 7-0136 7-0136 7-0108	301 303 304 301 300 307 308 300 400	150000 151104 154440 155110 15000 15000 15000 15000	00030468 00096457 0100964 01009075 00090130 01570773	10.7000 19.814.0 19.8004 10.8007 10.0100 10.0000 10.0730	7.3019

36 METALLURGISTS AND CHEMISTS HANDBOOK

SQUARES, CURES, SQUARE AND CURE ROOTS OF NUMBERS FROM

•	Square	Cubo	2q. Rest	Root	No.	Square	Cubo	Root.	Rest
_	100800	64481391	10.0110		451	P03401	91733851		7 066
ia ka	pé résa.	Septe Sed	20-0400	7 3743	450	204,504	91343408		
9	163400	65450527	80-0740	7 3864	453	905300	01050077		7.000
Ň.	163216	65030364	pp. 0000	7 3975	454	306116	0.1570004	21 307 3	7 085
1	164011	66430115	1011746	7 3955	455	207015	94190375		7 691
ю	104830	66013416	10. L484	7-4947	456	107010	94515516		7 607
7	TOTAS TOTAS	07439143 07017318	30. 1742 30. 1600	7.4108 7.4108	457	100764	95443993		7 700 7 700
N.	167 161	68417030	29.2437	7-4200	450	#10081	00700570		7 754
ó	riston	05012000	no. selle	7-4100	400	111000	97330000		7.730
13	168011	69426132	80.973T	7-4350	461	#125#1	9797 22B2 9862 12 18	0-40%	7 705
18	189744	60034518	30.3975	7.4490		913444			7 730
믯	E70980 E72300	79444087	39.3224	7-4479	404	#14300 #15300	99251847 99807344		7 730
14	178883	71473375	20 3715	7 4500	805	216335	100544015		7 743
d	173050	71001200	20.3051	7-4050	400	217190	torigatot	21 5870	7 732
17	17 188	71516713	00t p. Ot.	7.4710	407	218000	101847365	ST OFF	7.73
阊	174784	73034633	20-4430	7-4770	468	310004	101303131	4 7 7 7 1	7 7%
9	171901	71900090	30.6005 30.6030	7.46.00	410	\$1990T	303101700		7 76g 7 771
"	170400	7400000						,	
	277842 278084	746cBa6c	B. 3189	7-4048	100	oox#4x	204407111		7 180
	178000	7515144B. 73084467	80.5430 20.5070	7.5007	478	993784 993789	105154048		7 786
U	170770	70115014	PO 5013	7 51 30	473	334070	100400414		7 707
	180015	76765625	BO 0155	7 5185	475	aeşbeş	107171875		7.800
峋	181476	77308776	ac.6398 ₍	7 3 144	470	336576	107550176		7 609
焩	181310	77854483	PD-0540	7 5300	477	237530	100 531 333		7.81
ů.	184041	78409753	20.0861	7 5550	478	antite aross	10311331		7.810
Ä	:Ligon	79307000	20.7364		419	120,000	110101000		7.840
13	181761	Bendenet Bedat påll	sa. ydag so. ykyk	7 5537	484	132361	211164642	21 9317	1.841
뻐	180014		20.7546	7 5995	1.450	834354	211gBocd6	31.0543	
비	187480	81186737	20.0007	7 5954	483	aggang	112678557		7 846
넴	186350 180115	81740104 81123071	20.8327 20.8507	7 5770	485	234390	113370004		7 8 9 6
J.	200000	\$588 t 850	po Mileo	7 58.48	480	110100	114791256	88 0454	
izl	Lengée	83453453	10.0043	7 5200	1487	237300	115501303	31 00B1	7 867
剛	torfice.	84027078	20.9254		488	236144	E10314978		7 874
ø	192732	Betragto	30-9513 30-976s	7.0050	400	970191	2176-g0000		
100	teléco	Birgoo	J. 19700	1,000	480	MOTEO	11/400000	** -330	1 440
	Totals	Byyddrat Boyyddd	#1.0000 #1.013#		401 401	842881 843864	218370771 110005488		7 88g
8 5	TOTALS Equipment	86438307	Pt-0476		403	24,1940	210611157		
-	107136	67338384	\$6.4713	7 6180	494	244030	100533784	33 236t	7-005
Į,	taffoa5	60 : 11115	21.0090	7.6346	403	143023	131207375		
ű	198016	68716536	21 2187	7.6403	405	146016	111013036		
긔	100000	B0324013	21 1414 21 1660	7.646a 7.6517	407	347000 248004	121763473 123505002		- 4
ià IQ	900704 901001	80011500 00515500	PE 1800	7 6174	498	140001	144151400		
Ä	200 200	91199000	21.213.0	. 44	9000	0,00000			

SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS FROM 1 TO 1000

=	1		_	_					
No.	Square	Cube	Root	Cube Root	No.	Square	Cabe	Sq Root	Cube Root
100	151001	125751501	11 38 10	7 9473	351	301601	167454751	95-4714	8 rofe
501	352004	Εμό τούφολ	12 4054	7 94"6	552	301.01	15/3196608		8 2016
503	\$5100Q	127204527	22 4277	7 0528	5 5 3	105500	20-1112422	25 5100	8 20/1
204	254016	123004004		7 95Hz	5.54	100,031	L_101110#	45 5370	_ ~
\$0.5	355035	138 825 44	_	7.0034	5.5	12,0054	1 OUCCH E		8.2180
\$00	1400-7	130444310		7 grin6	440	300114	127,710		y 2330
507	\$4.010	110121541		7 97 19	5 7	110373	17/2503/91		8 2178
908	149001	111000111		7 9 94	5.8	311191	124241111		8.2327
200	259041	111872229		7 9843	213	312482	174076879		B 2377
510	100100	112021000	22.5032	7 phot	500	713000	175010000	13 0043	5. 14 20
	,		١.						
SEE	96tt#1	133432837	22 6051	7.004	56£	314721	176558481	21 6Re4	8.3475
511	107144	134717728		8 0000	562	315544	177504128		8.2524
513	263169	£350050y*	22 6495	8 0052	1/13	3 z fryfry	175451547	23.7210	8 2573
514	304100	111-00-44		8 0104	5/14	315000	1 2406144		8 2621
\$15	36 2 3 3 2	E VERSION T	22.0015	8 02 56	₹ €	\$19225	15 62145	21.769*	8 2670
210	20015	tt (Mage		8 0108	41-6	1201 /	1413214	21 1005	8 2719
517	261,80	# c4548915		X 0100	500	121450	184454401		6 2768
518	208324	15%3024,2		8 0 111	568	1120.4	141320111		8 3416
\$19		120,08145		Rossi	500	333761	184220000		8 1865
530	270400	£40008000	11 8035	ROTEZ	570	324900	192103000	33 8747	5. 2913
531	375445	141420761	22 8264	8 0466	571	120041	186160411	21 Sor6	8 2062
533	27.24%	142230048		8.0517	578	327184	18 149248		8 1010
\$25		14 10 5 5 16 7		Rosby	573	328329	12411541		8 3050
534	274576	141527524		8 00 20	574	12010	150110134		1 1107
525	275675	244 03175	72 9179	1 00 8	57.5	3 × 16	1,01001*5		8 1555
536	2750-5	145511570	22 914"	80-21	5-6	1 1-00	14110495		8 1203
547	277729	140.03284	22 957 5	A onna	517	117929	19220004	24 0408	4 3251
536	278134	147197952	31 0.83	8 OK 25	578	1,4084	1,1200557	44 0410	8 3300
520	279541	145035880		II o876	5"9	315240	104104519	24 OV 54	8 3348
530	280000	145877000	33 031.	3 0927	SNo	130400	102113000	24 0933	8 3,396
533	2Srgót	149721201	21 0434	8 0978	581	\$12461	100111041	24 1010	8 3443
532	28 1024	150508164		8 102R	583	3 54-24	401111101		8 3496
\$33	184080	15141945"	15 OWN	A sorg	483	3.102/50	12415525	4.1451	8 ,119
534	28414	1512, 1104	13 10A1	8 11 10	5%4	1110	1001 5 04	-4-17-1	× 1587
535	250225	144110 .4		8 (180	<44	142245	200.201674	44-1508	H 1624
536	287296	15 10002 /-		N 12-11	\$ 10 (141190	3 13 100 1		B 365a
	238 (69	1 clacket		R L MI	<47		3 - 2 - 30		. 7
538		155720872			5535	345-44			
5.39		150 CgoSto			550	145031	301110100		8 1575
3.40	291000	157404000	23 2370	8 1433	500	349100	205379000	11 1990	6.3871
541	202681	118140421	21 2794	8 1485	591	349281	2054350*3	24 3105	8 1910
542	203754	N800110 1	23 zhoo	8 1555	194		20 4746NA		
\$43	294549	100101001	21 1021	RICHL	593		20352-4		
544	301030	1/10/04/184	2 12,2	8 14 33	594	1528	2 4,5 74 71	4 ,521	3 400E
545	207025	totalsus.			595	121012	21-W1215 4		1 4108
Seb	208116	15071-5		4 1713	(76	3000	ale as of		94168
547	200 200	16/00,51			177		31- 11		2 4 .03
545	300 101	16 1400,405		8 1413	503	40.00	21351 19		
540:	301101	165460140		8 1584	5 10	358801	214) 1700		
130	304500	100375000	43 4511	0.1033	600	\$20000	110000000	14 494U	0.4345
1									

38 METALLURGISTS AND CHEMISTS' HANDBOOK

SQUARES, CORES, SQUARE AND CUBE ROOTS OF NUMBERS PROME

								_
No. Squ	cube Cube	Sq Root	Cube Root	No.	Square	Cube	Koot	Cube Root
6ot 36t:	001 1170H180	1 24 5151	8 4100	651	(42 (50)	275594451	25 5117	3.6668
603 361			8 4417	0.1	4.1.04	277107808		8 67 13
Dog: 3016			8 4454	6.3	4 1 100	3-44460-7		8 6757
504 30 1			N 4550	6,4	40 .14	1 9-10-64		8 6501
605 3//N			N 4517	6.55	4290.35	Atolti S		8 6845
600 shr:			R 4623	4.0	412,30	252300410		8.68aa
607 365.			K 4070	6.7	4 1549	18 1021 Pt		8 6014
606 3000			8 4 10	658	412204	384500343	25,0515	8 6978
600 370	S81 225360524	9 34 6 ** 9	H 4"03	659	414291	280191179	25 0710	
6to 3721	22695100	0.11,0083	8 4509	600	43,000	487496000	25 6905	8.7066
(
OTT 3733	111 22800913	1.24.7184	8 4556	661	435041	185804781	25 7000	8 7110
6L2 3741	(44 33933003)	4 24 7350	8 (405	05.1	4 7 41	290217525	25 7204	8 7154
DIS 375			8 4348	Let 2	4:9 %	201434747	15 , 458	8 7198
014 310			y 1304	003	44 3500	404254944		8 7242
OE5 174:			N . C TO	r= <	44	AND A BUR		8 7285
610 170			3 5000	14.0	44 15 1	20,620,4300		8 7339
617 3500	7		8 112	CH 3	411,00	206 3 306 1		B 7373
618 3519			8 54 5	04.45	4. 1	a photography a		8 7416
DEQ 3851			8 5224	firig	14 574	200418300		5. *40g
620 3H4.	100 43834800	0.24.5000	8 5.70	0,0	11,2000	100,61000	J 5 8844	5 7503
4			N6	6-4				
Dat, Tude			N 5116	6-1	1 0141	302111711		8 7547
622 3508	7 7 7 7		85442	0.1	4 × 84	35 404444	_	8 75go
624 340			N C L J	6.74	1 2 6	12452131		B 7054
015 190			85.00	1 4			. Jane	8 2728
620 (31)			4 11	10	4 4 7		/00/	804
617 141			N 10		150	112.55 1		B 1807
62H 194			2 4	0.3	1 /51	11 K 54		8 850
dag tost			A vide	15	at loci	113040510		8 2504
630, 3000		- 1	8 5720	080	4" 1470	311411000		8.7937
	, , , , , , ,					. , , , , ,		
631 1981	61 25121050	1 15 1 to.	8 4 772	682	4/1:61	115821241	the color	8 7980
612 100			8 (317	532	1/31/4	117214,68		8 8045
614 4700			N Nr.	34	4 124	1501145		3 4066
014 40		_	N + 201	125	4 5 4	14.2.1.5.44		4 4100
635 40 .			3 353	L.A.	4 441.45	1.1112 4	2 1 .5	8 8152
630 4.5			4 5 11/2	15	4 /	11.7.33	.6 1.1	5 4104
637 425			Action 24	P. 96	4 12/2	1 474 %		8 5/17
638 4 -	44 3 Mys 2"	1 - 1 - 1	N COURT	154		1257/101 2		
639 498	cat about, the	3 - 1-44	8.6232	689		2138.769		
640 4000	ion apartition	25.2082	24.12	oyo	4,0100	41,70000c	26.20.9	8 9300
	DB . 4	1	0.4	4				
641 410	ME 20177472		8 61.2	001	1,,191	3-00:0171		
645 4251			X 6367	567		331 1784		
643 4111			N. C. C. T.	(1933)	100	tt, hear	12()	8.8493
044 111			X	100		26 4		
645 4+60			3 401	CHU C		1		4 4478
640 11			4 446	1900	4 2 4 5			
647 4137				164		4 4 - 34 6		4
648 4130			4 - 34	Page 1	district	1.7		44100
650, 4325			8 0014	700		415150g/		
430 432	4035000	2 2 4421	0.0044	706	490000	143000000	20 4375	8 8790
			_					

SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS FROM 1 TO 1000

ia.	Square	Cube	Root	Cubr Root	10	Square	Cube	Sq Ruot	Cube
				-				-	
101	401401	344472101		3 5855	751	201001	421504751		g.ong
03	401904	345048408		H NH7 4	752	505504	43 (45000)		0 003
LO3	401300	547427037		N Not7	. 63	50 000	420051777		9 007
104	405010	Physical Court		8 1449	754	\$68510	4,5001004		0 101
05	44.012	3201034.34		1000 K	25.5	2 0016	43 104016		9 105
100	405430	351995116		8 9041	750	5 1510	411051110		9.100
97	400140	121231241	201 C3Q5	Ayons	757	5 010	41179Nog1		9 111
08	101104	354501012		8-4127	158	514504	435510511		9 117
OQ.	_	140400450		Batto	719	§10081	417345470		0-111
011	204100	357911000	20 0450	2 0311	700	577000	4,350,0000	27 3001	9.125
111	504521	350425411	26.6646	8.9251	761	570111	440711081	27.5862	0.120
11	500044	JOOUALEZE		8 9295	70 z	540044	443450738		0.111
13	508 100	102402002		8 93 17	163	582160	444194947		9 1 17
m	500700	101004144		N 41 8	754	54 sbuck	44 94 1744		0 141
	511235	105425575		R-9430	705	54 715	44 70 175		0 149
16		100100101		N-040a	200	536 56	449455005		0 140
12	-	36NO1513	40 - 7604	Xosos	707	443240	451-5 64 5		9 255
18	\$15524	1,0110111		8 Q545	768	sNgN24	452071752		9 157
to	\$16g01	172004050		8 9587	700	SQL LOI	454750000		9 161
90	518400	373348000	26 5328	8 0018	770	502000	450533000	27 7489	9 165
				4 . 6					6
11	S10841	374805361		8 9070	772	304441	455314011		0.100
	251194	370307048		8 9711	773	505084	450000045		9 17.
243	522720	37501300,		N -0253	773	\$4.655	401880017		0 177
724	* * *	1,0101474		N -2744	774	100000	4 40,44.1		0 181
	535575	1410 4114		4 3435 H . H . S	775	Contrary	45-451-15		9 189
110	-	3420511 "		H WH B	176	60 723	46 .345,0		
127	525520	141547641		N ports	717	605284	450007411		9 193
7 35		385825152		N ouse	778	005204	472720130		0 107
7,30	-	389017000		0.0000	779 780	608400	474552000		0.10
						1 .			
731	\$34361	300617801	27.0370	0.0083	781	500001	416179541	27 0464	0.200
734	535834	392221108	27 0555	0 0121	759	DE1544	475211705	27 904	9 21
733	557.28Q	30371251	1 0740	0 0104	7%3	UKO, 10	4,2001,201	3. 0411	9 217
734	554750	1-12110-001	1 0014	0.0034	754	(140.0	472700104	74 3003	y. 220
715	540225	397 80 4 5	. 119g	5 10	745	0.0445	4462 44.78		9. 224
730	541000	103058110	, LTA	0 ah7	7.30	0 - 1/4	44 CHALLS	14 O12	Q. 228
737	545100	400315555	47.54	0.0138	2 47	0.0100	45 48345 1	36 7818	Q. 23.
738	544544	401047272	27 IPH12	00100	7.58		474103772		
739	240111	403583410	37.124	d ofto	250		101100000		
740	547900	405334000	17 1039	0 0110	790	024100	493039000	28 100g	Q. 244
745	108042	406869011	27 2214	1040.0	701	625681	40101,671	25 1 242	0.24
743					7.2		400793088		
	553040				703		495017257		
	541516				*34	P 104 10			
745		7			- 25	f-1201	52 45,005		
793		41 vihogith			36	1 . 116			
747					- 27	6 5.34			
					243		503100503		
1	551001			U.0810	°u0	015401			
	1 502500	421875000			800		5110000000		
	302300	desol home	at Book	8,00,10			3 - 1 - 0 0 0 0 0 0 0	20.20m)	A 20'

40 METALLURGISTS AND CHEMISTS' HANDBOOK SQUARES, CURES, SQUARE AND CURE ROOTS OF NUMBERS FROM 1 TO 1000

No.	Square	Cube	Root	Cabe Root	No.	Square	Cube	Sq Root	Root
			_		-				
801	641601	513922401		9.2870	128	734301	616295051	20.1710	9.476
loz	643204	\$25840008		9.2000	844	"35004	618470208	29 1 8go	9.480
las	644500	517781627		Q. 2Q4 ^A	855	*2 bog	620650477	_	0.483
Bou	646416	519718404		9.2986	854	130310	612835864		9 457
805	644025	251000132		D 1034	Reg	,11032	9720347-4		9.49E
800	640635	\$31000016		g. tong	8 46	733736	077717010		9-494
507	921510	\$25457941		d' 1105	Rey	714449	029432703		9-4984
505	052864	527514112		9 5140	848	730104	611628717		0.501
lag	654481	520475120		9.1179	859	737881	033030770		9.500
810	650100	\$31441000	19:1002	9.5717	860	7390001	030030000	20.3130	y. 50g
إريا	657711	\$33411731	18 4 78 7	0.3255	86 t	741321	618277481	20. 1428	0.513
B2 21	059144	535187128	28 4050	0.1704	863	745044	610401019		0.517
111	66ogég	517107747		0.1112	Bh ;	744700	641745647		0.530
11	062530	53015 144		0 (120	864	740100	644074544		9 5244
815	664225	\$41141115		0.1408	405	744225	hirzlafize		9.5381
116	00 fly 60	543535490		0.1447	866	*100×F	610461300		9.5317
Ber.	06-440	545138514		9.1435	362	7 CEONG	051714301	29 4449	9 5354
818	000174	54"1434 2		0.1523	808	753474	0130,5011		9 539
119	67076t	549353250		Q 150I	Stig	75515L	65/13/1900		9-542
20	672400	551368000	25 6356	D-3599	870	750000	658303000	30-405B	9.546
	4								
Bar'	674041	553387661		9.3637	87E	758641	660776311		9.5301
21	67 50H4	\$5541224 ⁸ 557442767		0 1015	8 1	100111	665138617		0.5531
824	678076	55 44 hard		0 1-51	K-1	-6,4 6	00-62 624		0 5010
625	6806.5	50253 625		0 1-50	R s	-nsbzs	00002.471		0 5641
10	AR23 A	57 35 34,00		9 1427	8 6	w . d.	6 4222306		o 568)
817	0211036	1 1474 14		0 805	8 7	200120	0-4420134	20/1542	0.5710
Bzä	685554	\$0.200 £ 6 4	14 7150	0.1003	P.A	7*0884	COSTERS.	24 6111	0.5750
Bzg	687141	500717 10	B 7934	9.1440	King	271041	010141410	29 0479	9-579
3,0	688yoo	571787000	28 8097	9.3978	8.4o	774400	681472000	2G 0048	9.5834
!	, ,				00-		(4	10-4	0.6
Ogt'	600561	\$7 1856101		0.1010	RR1 Rh2	776161	681707841	20 0085	0.5865
151	Unique Unique	575010168		0.4053	881	777074	645jActi	10 715	9 5937
833 834	SOLCE	500001703		0 4130	A34	14544	nitore 3		y 5973
815	001/2	5 H H . N		0.4156	ARE	Non	thy 14,13	27 6741	0 0010
110	nightker	5414 DEE		0 4204	836	4.79	in objet	y 1. h	0.0046
17	zonship.	CHELL WAS C		9.4241	36.69	- M.P. Page	CHI THIS W	2 4.5	0 6081
038	702244	5484MO1-7		0 47 0	NAS.	157544	,0011100.		0 0118
130	701031	500580719		9.4116	9.50	*90321	*0 tos tho	19 5161	0.0154
640	705500	592704000		9-4154	8yo	792100	7049090000	20 8329	9 6190
					0			9	. 6.4
141	707251	594821121		0.4101	891	793881	707147971		0 6236
4.1	70%004	500047688		9 44 20	Roa Roa	795004	700713258		0.6363
843	110010	(30071151		9 4400	893	10031	714416084		0 0 2 0 B
845	111032	60114114		0 1211	894	401036	21001 / c		6 6 170
846	715710	005495110		0 45 4	500	401014	710 2 110		6 6406
847	11 400	hortyst.		0.4615	No. 2	houhou	*31 12*1		9.6441
648	710104	000400194	_	0 4453	He X	Non404	774130702		9 0472
640	120401	34000Q110		0.4000	Mgg	HoN 201	22011,000		9 6513
550				0.4727	000	510000	7.840000000		0.654

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SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS FROM 1 TO 1000

No.	Square	Cube	Root	Cube Root	No	Square	Cube	Root	Root
_			_						
pot	B11801	731433701		0.6585	951	101106	1212 Rooos		9 8130
101	811004.	75 LF TOFOR		0 00 10	953	800 (91	862No140N		9 837
DOJ.	N15400	730114121		9.6656	95)	golf zou	M64421111		Q Aun
1	817110	119 21121		9 5092	954	Moth	\$683,0664		9.844
901	Broase Broase			9.6727	276	013014	Brogh (Bri		0.847
906	911010	740141041		9.6703	050	011210 011210	8 646-491		0.551
	814404	7480t 1512		0.0799	948	01*764	8-011 A13		9 554 9 558
900	820181	751010130		-	010	010081	841974079		g. Rós.
to.	\$26100	753571000	4.4	0.0005	960	021000	584730000		9.864
		1337,000	1	Aroka'i	You	941000	024,30000	yu. 40.34	A-one
180	820001	7 thoshott	10.1818	06017	ofi	011111	ttrenst.		o 568
1 1	831744	758550528		9 0047	001	933531	847 003681		9 871
13	811100	70104514	10 2151	0.7012	06.1	915444	890177118		0 875
14	815105	201511 266			903	G20200	N. 1742 144		0 518
115	A17225	* Honoring		u toll	210	0.1224	HUNG , 2125		9.851
916	Bruoss	THE SING	to after	97115	906	9+1156	QUELIBOUR		p Alls.
117	Saosilo .	775004313		9 7154	or -	g, sobu	your tine		o 888
pa B	8427241	775030057		9 *184	gost	9,"014	00,040111	51 112"	o floa
pro	BAASOL	776151450		9.7376	960	918901	000153200		o Aost
140	Button	278688000	30.3315	9.7259	970	040900	At 10,2000	31 1448	9.899
NT.	BaBraz'	781120061		0.7204	971	943842	915498611	11 1600	9.901
22	5500E4	781777448		9 7329	973	Offige	SINTIONI,		9 005
10.3	921030	78611046"		9.7464	0"3	Q4*** 2Q	033102712		9 000
	Reine	7806590004		0.5490	9 4	gable h	A 4ctof11		0 013
196	855025	2014 4195		9 *455	0.4	geologis	Day Note L		0.0100
27	850420	יליבי סוער		0 1419	0 6	957575	9791141 5		0 010
44	801154	799175752		9 105	U.B	041430	\$125 aft, 1		9 927
	801041	801765080		0 -4.2	0.0	04441	918311739		0 030
30	864900	804357000		0.7010	y80	900400	941193000		9 932
	1								
18	R66761	806054401	10 (111)	9 7645	gA t	962361	9440-0141	\$1 1700	9.036
132	808614	809111408		9.7680	07.1	904134	641449449	\$1. \$16g	9.4390
IJJ	Broady	gt110034.		0 ***! 4	641	gno a Nu	gaylinzolin	11 3 125	9 94 10
134	2.5670	gra goest		0 3	0.74	QC A 1	45 6 7 1		4 6464
	374775	11,1001.2		y. 145	QMS	P.0157	Gesty 105 c	1.1847	0.0103
3	Anhogh Annoho	620075556		9 1510	Opt.	0,11100	0 414 730		9 9531
37	6119644	Massy 672		UIUI O	الي 18اي	0.1100	0012-190		9 950
	841741	827910010		9 7914	glig	9 8131	UF-\$4 2 QD, 301000		0 0 500
NO.	843600	830584000		9 7959	990	090100	01010000		9 g6 (1
	1		1						1
141	885481	833347621	10 67 57	9.7003	100	1Ros Ro	071141371	11 4801	a offer
163	RR7 304	815806868	10 6010	9 501B	992	941004	016101455	st agho	Q Q7 L1
M3	88014v	8385618e*		9.8063	901	ολόσευ	9"914001"	LL SI IQ	0 0.00
MA	9911 I/S	41212554		g floy"	994	yste in	All Piles		g gAdd
MŞ	893072	S4 typhout			200	QUOU	WAY C		ر والو ب
•	804016	Authorite		O RIFE	guh.	003517	year of		y 9566
24	-University	8401,215		y Haut	94	JU 1000	4010,401		0.0000
444	898104	NS10 1391		9 H216	ggN	UU/nois4	994011994		9 9933
3 2 2 2 2	000001	8546-0540		0 1110 v	990	guñost	00,00,000		0.0003
	900 500	\$57,575000	30.0311	A 0702	.000	1000000	000000000	11 0139	

LOGARITHMS OF NUMBERS

N	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11 12	0414 0792	0453 0828	0492 0864	0531 0899	0569 0934	0607 0969	0645 1004	0682 1038	0719 1072	0755 1106
13 .	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16 17	2041 2304	2068 2330	2095 2355	2122 2380	2148 2405	2175 2430	2201 2455	2227 2480	2253 2504	2279 2529
18	$\begin{array}{c} 2553 \\ 2553 \end{array}$	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2876	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22 23	3424 3617	3444 3636	3464 3655	3483 3674	3502 3692	3522 3711	3541 3729	3560 3747	3579 3766	3598 3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27 28	4314 4472	4330 4487	4346 4502	4362 4518	4378 4533	4393 4548	4409 4564	4425 4579	4440 4594	4456 4609
29 29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092 5224	5105 5237	5119 5250	5132 5263	5145 5276	5159 5289	5172 5302
33 34	5185 5315	5198 5328	5211 5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
87	5682	5694 5809	5705 5821	5717 5832	5729 5843	5740 5855	5752 5866	5763 5877	5775 5888	5786 5899
38 39	5798 5911	5922	5933	59 44	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232 6335	6243 6345	6253 6355	6263 6365	6274 6375	6284 6385	6294 6395	6304 6405	6314 6415	6325 6425
43 44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48 49	6812 6902	6821 6911	6830 6920	6839 6928	6848 6937	6857 6946	6866 6955	6875 6964	6884 6972	6893 6981
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235
53 54	7243 7324	7251 7332	7259 7340	7267 7348	7275 7356	7284 7364	7292 7372	7300 7380	7308 7388	7316 7396
i	·	<u> </u>		<u> </u>	[<u> </u>			

LOGARITHMS OF NUMBERS.—Concluded

N	0	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917
62	7924	7931	7938	7 945	7952	7959	7966	7973	7980	7987
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686
74 75 76	8692 8751 8808	8698 8456 8814	8704 8762 8820	8710 8768 8825	8716 8774 8831	8722 8779	8727 8785 8842	8733 8791 8848	8739 8797	8745 8802
77 78 79	8865 8921 8976	8871 8927 8982	8876 8932 8987	8882 8938 8993	8887 8943 8998	8837 8893 8949 9004	8899 8954 9009	8904 8960 9015	8854 8910 8965 9020	8859 8915 8971 9025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390
87	9395	94 00	9405	9410	9415	9420	9425	9430	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9941	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9998	9996

44 METALLURGISTS AND CHEMISTS' HANDBOOK

NATURAL SINES AND COSINES

NOTE.—For cosines use right-hand column of degrees and lower line of tenths.

HOTE				P10-110							
Deg.	0.0	°0 .1	°0 .2	°0.3	°0.4	°0 .5	°0.6	°0 .7	8.00	°0.9	
0° 1 2 3 4	0.0175 0.0349 0.0523	0 .0017 0 .0192 0 .0366 0 .0541 0 .0715	0.0209 0.0384 0.0558	0 .0227 0 .0401 0 .0576	0 .0244 0 .0419 0 .0593	0 .0262 0 .0436 0 .0610	0 .0279 0 .0454 0 .0628	0 .0297 0 .0471 0 .0645	0 .0314 0 .0488 0 .0663	0 .0332 0 .0506 0 .0680	89 88 87 86 85
5 6 7 8 9	0.1045 0.1219 0.1392	0 .0889 0 .1063 0 .1236 0 .1409 0 .1582	0.1080 0.1253 0.1426	0.1097 0.1271 0.1444	0.1115 0.1288 0.1461	0 .1132 0 .1305 0 .1478	0.1149 0.1323 0.1495	0.1167 0.1340 0.1513	0.1184 0.1357 0.1530	0.1201 0.1374 0.1547	84 83 82 81 80°
10° 11 12 13 14	0 .1908 0 .2079 0 .2250	0.1754 0.1925 0.2096 0.2267 0.2436	0.1942 0.2113 0.2284	0.1959 0.2130 0.2300	0.1977 0.2147 0.2317	0.1994 0.2164 0.2334	0.2011 0.2181 0.2351	0 .2028 0 .2198 0 .2368	0 .2045 0 .2215 0 .2385	0 .2062 0 .2232 0 .2402	79 78 77 76 75
15 16 17 18 19	0.2756 0.2924 0.3090	0 .2605 0 .2773 0 .2940 0 .3107 0 .3272	0.2790 0.2957 0.3123	0.2807 0.2974 0.3140	0.2823 0.2990 0.3156	0.2840 0.3007 0.3173	0.2857 0.3024 0.3190	0.2874 0.3040 0.3206	0 .2890 0 .3057 0 .3223	0.2907 0.3074 0.3239	74 73 72 71 70°
20° 21 22 23 24	0.3584 0.3746 0.3907	0.3437 0.3600 0.3762 0.3923 0.4083	0.3616 0.3778 0.3939	0.3633 0.3795 0.3955	0.3649 0.3811 0.3971	0.3665 0.3827 0.3987	0.3681 0.3843 0.4003	0.3697 9.3859 0.4019	0.3714 0.3875 0.4035	0.3730 0.3891 0.4051	69 68 67 66 65
25 26 27 28 29	0 .4384 0 .4540 0 .4695	0 .4242 0 .4399 0 .4555 0 .4710 0 .4863	0.4415 0.4571 0.4726	0.4431 0.4586 0.4741	0 .4446 0 .4602 0 .4756	0.4462 0.4617 0.4772	0 .4478 0 .4633 0 .4787	0 .4493 0 .4648 0 .4802	0 .4509 0 .4664 0 .4818	0.4524 0.4679 0.4833	64 63 62 61 60°
30° 31 32 33 34	0.5150 0.5299 0.5446	0.5015 0.5165 0.5314 0.5461 0.5606	0.5180 0.5329 0.5476	0.5195 0.5344 0.5490	0 .5210 0 .5358 0 .5505	0.5225 0.5373 0.5519	0.5240 0.5388 0.5534	0 .5255 0 .5402 0 .5548	0.5270 0.5417 0.5563	0.5284 0.5432 0.5577	59 58 57 56 55
35 36 37 38 39	0.5878 0.6018 0.6157	0 .5750 0 .5892 0 .6032 0 .6170 0 .6307	0.5906 0.6046 0.6184	0.5920 0.6060 0.6198	0.5934 0.6074 0.6211	0.5948 0.6088 0.6225	0.5962 0.6101 0.6239	0.5976 0.6115 0.6252	0.5990 0.6129 0.6266	0.60C4 0.6143 0.6280	54 53 52 51 50°
40° 41 42 43 44	0.6561 0.6691 0.6820	0 .6441 0 .6574 0 .6704 0 .6833 0 .6959	0.6587 0.6717 0.6845	0.6600 0.6730 0.6858	0 .6613 0 .6743 0 .6871	0.6626 0.6756 0.6884	0 .6639 0 .6769 0 .6896	0 .6652 0 .6782 0 .6909	0.6665 0.6794 0.6921	0.6678 0.6807 0.6934	49 48 47 46 45
	°1 .0	°0.9	°0.8	°0.7	°0.6	°0.5	°0.4	°0.3	°0 .2	°0.1	Deg.

NATURAL SINES AND COSINES.—Concluded

Deg.	0.0	°0 .1	℃.2	°0.3	°0.4	°0 .5	°0.6	°0 .7	8. 0°	e. 0°	
45 46 47 48 49		0.7206 0.7325 0.7443	0 .7218 0 .7337 0 .7455	0 .7230 0 .7349 0 .7466	0 .7242 0 .7361 0 .7478	0 .7254 0 .7373 0 .7490	0 .7266 0 .7385 0 .7501	0 .7278 0 .7396 0 .7513	0 .7290 0 .7408 0 .7524	0 .7302 0 .7420 0 .7536	44 43 42 41 40°
50° 51 52 53 54	0.7771 0.7880 0.7986	0.7782 0.7891 0.7997	0.7793 0.7902 0.8007	0.7804 0.7912 0.8018	0 .7815 0 .7923 0 .8028	0 .7826 0 .7934 0 .8039	0.7944	0 .7848 0 .7955 0 .8059	0 .7859 0 .7965 0 .8070	0.7869 0.7976 0.8080	39 38 37 36 35
55 56 57 58 59	0 .8290 0 .8387 0 .8480	0 .8300 0 .8396 0 .8490	0 .8310 0 .8406 0 .8499	0 .8320 0 .8415 0 .8508	0 .8329 0 .8425 0 .8517	0 .8339 0 .8434 0 .8526	0 .8251 0 .8348 0 .8443 0 .8536 0 .8625	0 .8358 0 .8453 0 .8545	0 .8368 0 .8462 0 .8554	0 .8377 0 .8471 0 .8563	34 33 32 31 30°
60° 61 62 63 64	0.8746 0.8829	0 .8755 0 .8838 0 .8918	0 .8763 0 .8846 0 .8926	0 .8771 0 .8854 0 .8934	0 .8780 0 .8862 0 .8942	0 .8788 0 .8870 0 .8949	0 .8712 0 .8796 0 .8878 0 .8957 0 .9033	0.8805 0.8886 0.8965	0 .8813 0 .8894 0 .8973	0.8821 0.8902 0.8980	29 28 27 26 25
65 66 67 68 69	0 .9063 0 .9135 0 .9205 0 .9272 0 .9336	0.9143 0.9212 0.9278	0.9150 0.9219 0.9285	0.9157 0.9225 0.9291	0.9164 0.9232 0.9298	0 .9171 0 .9239 0 .9304	0.9178 0.9245 0.9311	0.9184 0.9252 0.9317	0 .9191 0 .9259 0 .9323	0.9198 0.9265 0.9330	24 23 22 21 20°
70° 71 72 73 74	0 .9397 0 .9455 0 .9511 0 .9563 0 .9613	0.9461 0.9516 0.9568	0 .9466 0 .9521 0 .9573	0 .9472 0 .9527 0 .9578	0.9478 0.9532 0.9583	0 .9483 0 .9537 0 .9588	0 .9489 0 .9542 0 .9593	0 .9494 0 .9548 0 .9598	0 .9500 0 .9553 0 .9603	9 .9505 0 .9558 0 .9608	19 18 17 16 15
75 76 77 78 79	0.9659 0.9703 0.9744 0.9781 0.9816	0.9707 0.9748 0.9785	0.9711 0.9751 0.9789	0.9715 0.9755 0.9792	0.9720 0.9759 0.9796	0.9724 0.9763 0.9799	0 .9728 0 .9767 0 .9803	0 .9732 0 .9770 0 .9806	0.9736 0.9774 0.9810	0.9740 0.9778 0.9813	14 13 12 11 10°
80° 81 82 83 84	0 .9848 0 .9877 0 .9903 0 .9925 0 .9945	0.9880 0.9905 0.9928	0.9882 0.9907 0.9930	0.9885 0.9910 0.9932	0.9888 0.9912 0.9934	0.9890 0.9914 0.9936	0.9893 0.9917 0.9938	0.9895 0.9919 0.9940	0.9898 0.9921 0.9942	0.9900 0.9923 0.9943	9 8 7 6 5
85 86 87 88 89	0.9976 0.9986 0.9994	0 .9977 0 .9987 0 .9995	0 .997 8 0 .9988	0.9979 0.9989 0.9996	0.9980 0.9990 0.9996	0.9981 0.9990 0.9997	0 .9971 0 .9982 0 .9991 0 .9997 1 .000	0 .9983 0 .9992 0 .9997	0 .9984 0 .9993	0 .9985 0 .9993	4 3 2 1 0°
	°1 .0	°0.9	°0.8	°0 .7	°0.6	°0.5	°0.4	∞.3	•0.2	°0.1	Deg.

Note.—For cosines use right-hand column of degrees and lower line of tenths.

NATURAL TANGENTS AND COTANGENTS

NOTE.—For cotangents use right-hand column of degrees and lower line of tenths

						TUB					
Deg.	0.0°	°0.1	°0 .2	°0.3	°0.4	°0 .5	°0.6	°0.7	°0.8	°0.9	
0° 1 2 3 4	0 .0175 0 .0349 0 .0524	0.0192 0.0367 0.0542	0.0209 0.0384 0.0559	0.0227 0.0402 0.0577	0.0244 0.0419 0.0594	0.0262 0.0437 0.0612	0.0279 0.0454 0.0629	0.0297 0.0472 0.0647	0.0314 0.0489 0.0664	0.0507	89 88 87 86 85
56789	0 .1051 0 .1228 0 .1405	0.1069 0.1246 0.1423	0.0910 0.1086 0.1263 0.1441 0.1620	0.1104 0.1281 0.1459	0.1122 0.1299 0.1477	0.1139 0.1317 0.1495	0.1157 0.1334 0.1512	0.1175 0.1352 0.1530	0.1192 0.1370 0.1548	0.1210 0.1388 0.1566	84 83 82 81 80°
10° 11 12 13 14	0 .1944 0 .2126 0 .2309	0 .1962 0 .2144 0 .2327	0 .1799 0 .1980 0 .2162 0 .2345 0 .2530	0.1998 0.2180 0.2364	0.2016 0.2199 0.2382	0 .2035 0 .2217 0 .2401	0 .2053 0 .2235 0 .2419	0.2071 0.2254 0.2438	0 .2089 0 .2272 0 .2456	0.2107 0.2290 0.2475	79 78 77 76 75
15 16 17 18 19	0 .2867 0 .3057 0 .3249	0.2886 0.3076 0.3269	0 .2717 0 .2905 0 .3096 0 .3288 0 .3482	0.2924 0.3115 0.3307	0.2943 0.3134 0.3327	0.2962 0.3153 0.3346	0.2981 0.3172 0.3365	0.3000 0.3191 0.3385	0.3019 0.3211 0.3404	0.3038 0.3230 0.3424	74 73 72 71 70°
20° 21 22 23 24	0.3839 0.4040 0.4245	0.3859 0.4061 0.4265	0.3679 0.3879 0.4081 0.4286 0.4494	0.3899 0.4101 0.4307	0.3919 0.4122 0.4327	0.3939 0.4142 0.4348	0.3959 0.4163 0.4369	0.3979 0.4183 0.4390	0 .4000 0 .4204 0 .4411	0.4020 0.4224 0.4431	69 68 67 66 65
25 26 27 28 29	0 .4877 0 .5095 0 .5317	0 .4899 0 .5117 0 .5340	0.4706 0.4921 0.5139 0.5362 0.5589	0 .4942 0 .5161 0 .5384	0 .4964 0 .5184 0 .5407	0.4986 0.5206 0.5430	0 .5008 0 .5228 0 .5452	0 .5029 0 .5250 0 .5475	0.5051 0.5272 0.5498	0.5073 0.5295 0.5520	64 63 62 61 60°
30° 31 32 33 34	0.6009 0.6249 0.6494	0.6032 0.6273 0.6519	0.5820 0.6056 0.6297 0.6544 0.6796	0.6080 0.6322 0.6569	0.6104 0.6346 0.6594	0.6128 0.6371 0.6619	0.6152 0.6395 0.6644	0.6176 0.6420 0.6669	0 .6200 0 .6445 0 .6694	0.6224 0.6469 0.6720	59 58 57 56 55
35 36 37 38 39	0.7265 0.7536 0.7813	0.7292 0.7563 0.7841	0.7054 0.7319 0.7590 0.7869 0.8156	0.7346 0.7618 0.7898	0.7373 0.7646 0.7926	0.7400 0.7673 0.7954	0.7427 0.7701 0.7983	0.7454 0.7729 0.8012	0.7481 0.7757 0.8040	0.7508 0.7785 0.8069	54 53 52 51 50°
40° 41 42 43 44	0.8693 0.9004 0.9325	0 .8724 0 .9036 0 .9358	0.8451 0.8754 0.9067 0.9391 0.9725	0 .8785 0 .9099 0 .9424	0 .8816 0 .9131 0 .9457	0 .8847 0 .9163 0 .9490	0.8878 0.9195 0.9523	0.8910 0.9228 0.9556	0.8941 0.9260 0.9590	0.8972 0.9293 0.9623	49 48 47 46 45
	°1.0	°0 .9	8.0°	°0.7	∾.6	°0.5	°0 .4	°0.3	⁰0.2	°0 .1	Deg.

NATURAL TANGENTS AND COTANGENTS.—Concluded

1				 : 							
Deg.	℃.0	°0.1	° 0.2	°0.3	°0.4	°0.5	°0.6	°0.7	% .8	%.9	
45 46 47 48 49	1 .0355 1 .0724 1 .1106	1 .0392 1 .0761 1 .1145	1 .0428 1 .0799 1 .1184	1 .0464 1 .0837 1 .1224	1 .0501 1 .0875 1 .1263		1 .0575 1 .0951 1 .1343	1 .0612 1 .0990 1 .1383	1 .0649 1 .1028 1 .1423	1 .1463	
50° 51 52 53 54	1 .2349 1 .2799 1 .3270	1 .2393 1 .2846 1 .3319	1 .2437 1 .2892 1 .3367	1 .2482 1 .2938 1 .3416	1 .2527 1 .3985 1 .3465	1 .2131 1 .2572 1 .3032 1 .3514 1 .4019	1 .2617 1 .3079 1 .3564	1 .2662 1 .3127 1 .3613	1 .2708 1 .3175 1 .3663	1 .2753 1 .3222 1 .3713	39 38 37 36 35
55 56 57 58 59	1.4826 1.5399 1.6003	1 .4882 1 .5458 1 .6066	1 .4938 1 .5517 1 .6128	1 .4994 1 .5577 1 .6191	1 .5051 1 .5637 1 .6255	1.4550 1.5108 1.5697 1.6319 1.6977	1 .5166 1 .5757 1 .6383	1 .5224 1 .5818 1 .6447	1 .5282 1 .5880 1 .6512	1.5941 1.6577	34 83 82 31 30°
60° 61 62 63 64	1 .8040 1 .8807 1 .9626	1 .8115 1 .8887 1 .9711	1 .8190 1 .8967 1 .9797	1 .8265 1 .9047 1 .9883	1 .8341 1 .9128 1 .9970	1.7675 1.8418 1.9210 2.0057 2.0965	1 .8495 1 .9292 2 .0145	1 .8572 1 .9375 2 .0233	1 .8650 1 .9458 2 .0323	1 .8728 1 .9542 2 .0413	29 28 27 26 25
65 66 67 68 69	2 .3559 2 .4751	2 .2566 2 .3673 2 .4876	2 .2673 2 .3789 2 .5002	2 .2781 2 .3906 2 .5129	3 .2889 2 .4023 2 .5257	2.1943 2.2998 2.4142 2.5386 2.6746	2 .8109 2 .4262 2 .5517	2 .3220 2 .4383 2 .5649	2 .3332 2 .4504 2 .5782	2 .3445 2 .4627 2 .5916	24 23 22 21 20°
70° 71 72 73 74	3 .0777 3 .2709	2 .9208 3 .0961 3 .2914	2.9375 3.1146 3.3122	2 .9544 3 .1334 3 .3332	2.9714 3.1524 3.3544	2.9887 2.1716	3.0061 3.1910 3.3977	3.0237 3.2106 3.4197	2 .0415 3 .2305 3 .4420	3 .0595 3 .2506 3 .4646	19 18 17 16 15
76 77 78	3 .7321 4 .0108 4 .3315 4 .7046 5 .1446	4 .0408 4 .3662 4 .7453	4.0713 4.4015 4.7867	4 .1022 4 .4374 4 .8288	4.1335 4.4737 4.8716	4.1653 4.5107 4.9152	4.1976 4.5483 4.9594	4 .2303 4 .5864 5 .0045	4 .2635 4 .6252 5 .0504	4 .2972 4 .6646 5 .0970	14 13 12 11 10°
81 82	5 .6713 6 .3138 7 .1154 8 .1443 9 .5144	6.3859 7.2066 8.2636	6 .4596 7 .3002 8 .3863	6 .5350 7 .3962 8 .5126	6.6122 7.4947 8.6427	6 .6912 7 .59 58	6.7720 7.6996 8.9152	6 .8548 7 .8062 9 .0579	6 .9395 7 .9158 9 .2052	7 .0264 8 .0285 9 .3572	9 8 7 6 5
85 86 87 88 89	11 .43 14 .30 19 .08 28 .64 57 .29	14.67 19.74	15.06 20.45 31.82	15.46	15 .89 22 .02 35 .80	12.71 16.35 22.90 38.19 114.6	16.83 23.86	17.34 24.90 44.07	26.03 47.74	27 .27	4 3 2 1 0°
	°1.0	°0.9	°0.8	°0.7	°0.6	°0.5	°0.4	°0.3	°0.2	° 0.1	Deg.

Note.—For cotangents use right-hand column of degrees and lower line of tenths.

ANALYTIC GEOMETRY

The Straight Line.—The equation of the straight line in its simplest form is $\frac{x}{a} + \frac{y}{b} = 1$, where a and b are the intercepts

of the line on the axes of X and Y respectively.

The other useful equations of the straight line are: y = mx + b, where m is the tangent which the line makes with the axis of X. The equation of a line passing through a given point (x_1, y_1) is $y - y_1 = m(x - x_1)$ where m is entirely indeterminate, since any number of lines may pass through a point. The equation of a line passing through two points is

$$y-y_1=\frac{y_2-y_1}{x_2-x_1}(x-x_1)$$

The distance between two points x_1 , y_1 and x_2 , y_2 is:

$$D = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Distance from a point x_1 , y_1 to a line ax + by + c = 0 is:

$$\dot{d} = \frac{ax_1 + by_1 + c}{\sqrt{a^2 + b^2}}$$

The equation of an angle Φ between two lines y = mx + b and y = m'x + b' is:

$$\tan \Phi = \frac{m'-m}{1+mm'} \quad .$$

The Circle.—The circle is the locus of all points in a plane equidistant from a given point.

The equation of a circle whose center lies at the origin is:

$$x^2+y^2=r^2.$$

If its center lies at (a, b):

$$(x-a)^2 + (y-b)^2 = r^2$$

If the origin lies on the left extremity of the diameter, the equation is:

 $(x-r)^2 + (y-0)^2 = r^2$ (as above)

or simplifying

$$y^2 = 2rx - x^2$$

The Ellipse.—The ellipse is the locus of a point moving in a plane so that the sum of its distances from two points in the plane is a constant. The ratio of the constant sum (the major diameter) to the distance between the foci is known as the eccentricity, e.

The area of an ellipse $= \pi$ times the product of the semi-diam-

eters.

The equation of the ellipse is

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$
 (center at the origin)

The tangent to the above ellipse through the point of tangency x_1 , y_1 is

$$\frac{xx_1}{a^2} + \frac{yy_1}{b^2} = 1$$

The Parabola.—The parabola is the locus of a point moving in a plane so that its distance from a point (the focus) in the plane is always equal to its distance from a line (the directrix) in the plane. Its equation, the curve passing through the origin and its focus lying on the axis of X is $y^2 = 4px$, polar coördinates $\rho = p \sec^2 \frac{\theta}{2}$, where 4p is the double ordinate through the focus. A tangent to a parabola through the point of tangency x_1, y_1 , is $yy_1 = p(x + x_1)$.

The tangent at any point makes equal angles with the axis

and a line from the point of tangency to the focus. The parab-

ola has no finite asymptotes.

The Hyperbola.—The hyperbola is the locus of a point moving in a plane so that the differences of its distances from two fixed points in the plane is a constant. Its equation, with its center at the origin and its foci on the axis of x is

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$$

Equilateral hyperbola: $x^2 - y^2 = a^2$.

Equilateral hyperbola referred to its axes as asymptotes: $xy = c^2$ (This is the isothermal curve of pressure and volume in gases).

Equation of the asymptotes

$$\frac{x}{a} = \frac{y}{b}; \frac{x}{a} = -\frac{y}{b}$$

The tangent to a hyperbola bisects the angle formed by the

two lines drawn from the point of tangency to the foci.

The Cycloid.—The cycloid is the curve generated by a point in the circumference of a circle rolling on a straight line. It consists of an infinite number of equal arches.

$$x = a \cos^{-1}\frac{a - y}{a} - \sqrt{2ay - y^2} \text{ or } \begin{cases} x = a(\theta - \sin \theta) \\ y = a(1 - \cos \theta) \end{cases}$$

The Epicycloid and Hypocycloid.—The epicycloid is generated by a point in the circumference of a circle rolling upon another circle. The hypocycloid is the curve generated by a point on the circumference of a circle rolling inside another circle.

Epicycloid
$$\begin{cases} x = (a+b)\cos\theta - b\cos\frac{a+b}{b}\theta \\ y = (a+b)\sin\theta - b\sin\frac{a+b}{b}\theta \end{cases}$$
Hypocycloid
$$\begin{cases} x = (a-b)\cos\theta + b\cos\frac{a-b}{b}\theta \\ y = (a-b)\sin\theta - b\sin\frac{a-b}{b}\theta \end{cases}$$

where a is the radius of the main circle, and b of the generating circle.

Cubical Parabola.—Formula, $a^2y = x^3$. Semicubical Parabola.—Formula, $ay^2 = x^2$.

Witch of Agnesi.—Formula,
$$y = \frac{8a^2}{x^2 + 4a^2}$$
.

Cissoid of Diocles.—Formula,
$$y^2 = \frac{x^3}{2a - x}$$

$$\rho = 2a \tan \theta \sin \theta.$$

This and the conchoid were invented to solve the problems of the duplication of the cube, *i.e.*, given a cube, a^3 , whose side is a, to construct the side of a cube, $2a^3$.

Lemniscate of Bernouilli.—Formula, $(x^2 + y^2)^2 = a^2(x^2 - y^2)$ $\rho^2 = a^2 \cos \theta$.

This and the following have a singular point at 0, 0.

Strophoid.—Formula,
$$y^2 = x^2 \left(\frac{a - x}{a + x} \right)$$

 $\rho = a(\cos \theta - \sin \theta \tan \theta).$

Cardioid.—Formula,
$$x^2 + y^2 + ax = a\sqrt{x^2 + y^2}$$

$$\begin{cases} x = a \cos \theta & (1 - \cos \theta) \\ y = a \sin \theta & (1 - \cos \theta) \\ \rho = a(1 - \cos \theta) \end{cases}$$

This is a special case of the epicycloid in which the generating circles are equal.

The Probability Curve.—Formula, $y = e^{-x^2}$.

The Caternary.—The caternary is the curve assumed by a uniform, completely flexible cord supported at its two ends. Its equation is

$$y = \frac{a}{2} \left(e^{\frac{z}{a}} + e^{-\frac{z}{a}} \right)$$

where e is the base of the Napierian system of logarithms.

The Involute.—The involute is the curve described by a point in a string which is being kept taut and unwound from a cylinder.

 $\begin{cases} x = a(\cos\theta + \theta\sin\theta) \\ y = a(\sin\theta + \theta\cos\theta) \end{cases}$ $\theta = \frac{\sqrt{\rho^2 - a^2}}{a} - \tan^{-1} \frac{\sqrt{\rho^2 - a^2}}{a}$

The Spiral of Archimedes is a curve described by the extremity of a radius vector which lengthens in proportion to the angle traversed. That is, the turns are equidistant from each other.

$$\rho = a\theta$$

Hyperbolic Spiral.—Formula, $\rho\theta = a$. Logarithmic Spiral.—Formula, $\rho = e^{a\theta}$. Lituus.—Formula, $\rho^2\theta = a^2$.

CALCULUS

Elementary Differentials

$$d(c) = 0$$

$$d(x) = 1$$

$$d(cu) = cdu$$

$$d(cx) = c$$

or

$$d(u \pm v \pm w ...) = du \pm dv \pm dw ...$$

$$d(uv) = vdu + udv$$

$$d(uvw) = vwdu + vwdv + uvdw$$

$$\frac{d(uvw)}{uvw} = \frac{du}{u} + \frac{dv}{v} + \frac{dw}{w}$$

$$d(u^n) = nu^{n-1}du; \ d(x^n) = nx^{n-1}$$

$$d \frac{u}{v} = \frac{vdu - udv}{v^2}; \ d\left(\frac{1}{v}\right) = \frac{dv}{v^2}; \ d\left(\frac{1}{x}\right) = -\frac{1}{x^2}$$

$$d(\sin x) = \cos x \qquad d(\tan x) = \sec^2 x$$

$$d(\sec x) = \sec x \tan x \qquad d(\cos x) = -\sin x$$

$$d(\cot x) = -\csc^2 x \qquad d(\csc x) = -\csc x \cot x$$

$$d \sin^{-1}u = \frac{du}{\sqrt{1 - u^2}} \qquad d \tan^{-1}u = \frac{du}{1 + u^2}$$

$$d \sec^{-1}u = \frac{du}{u\sqrt{u^2 - 1}} \qquad d \csc^{-1}u = -\frac{du}{\sqrt{1 - u^2}}$$

$$d \cot^{-1}u = -\frac{du}{1 + u^2} \qquad d \csc^{-1}u = -\frac{du}{u\sqrt{u^2 - 1}}$$

$$d \log_a u = \log_a e \cdot \frac{du}{u}; \ d \log_a x = \log_a e = \frac{1}{x}$$

$$d \log_a u = a^u \log_a adu$$

$$de^u = e^u du$$

Fundamental Integrals¹

$$\int adx = ax$$

$$\int af(x)dx = a \int f(x)dx$$

$$\int \frac{dx}{x} = \log x$$

$$\int x^m dx = \frac{x^{m+1}}{m+1}, \text{ when } m \text{ is different from } -1$$

$$\int e^x dx = e^x$$

$$\int a^x \log a dx = a^x$$

$$\int \frac{dx}{1+x^2} = \tan^{-1} x$$

$$\int \frac{dx}{\sqrt{1-x^2}} = \sin^{-1} x$$

$$\int \frac{dx}{x\sqrt{x^2-1}} = \sec^{-1} x$$

$$\int \frac{dx}{\sqrt{2x-x^2}} = \text{vers}^{-1} x$$

¹ For the more complicated integrals, see B. O. Pierces' "Short Table of Integrals" and the various works on integral calculus.

$$\int \sin x dx = -\cos x$$

$$\int \cot x dx = \log \sin x$$

$$\int \tan x dx = -\log \sin x$$

$$\int \tan x dx = -\cot x$$

$$\int \sec^2 x dx = \tan x$$

$$\int \csc^2 x dx = -\cot x$$

$$\int [f(x) + \varphi(x) + \psi(x)] dx = \int f(x) dx + \int \varphi(x) dx + \int \psi(x) dx$$

$$\int u dv = uv - \int v du \quad \text{where } u \text{ and } v \text{ are functions of } x$$

$$\int u \frac{dv}{dx} dx = uv - \int v \frac{du}{dx} dx$$

$$\int \sin^2 x dx = -\frac{1}{2} \cos x \sin x + \frac{1}{2} x$$

$$\int \sin^3 x dx = -\frac{1}{2} \cos x (\sin^2 x + 2)$$

$$\int \sin^n x dx = -\frac{\sin^{n-1} x \cos x}{n} + \frac{n-1}{n} \int \sin^{n-2} x dx$$

$$\int \cos^2 x dx = \frac{1}{2} \sin x \cos x + \frac{1}{2} x$$

$$\int \cos^3 x dx = \frac{1}{2} \sin x \cos^2 x + \frac{1}{2} x$$

$$\int \sin x \cos x dx = \frac{1}{2} \sin^2 x$$

$$\int \sin^n x dx = \frac{\tan^{n-1} x \cos x}{n} + \frac{n-1}{n} \int \cos^{n-2} x dx$$

$$\int \sin x \cos x dx = \frac{1}{2} \sin^2 x$$

$$\int \tan^n x dx = \frac{\tan^{n-1} x}{n-1} - \int \tan^{n-2} x dx$$

$$\int \cot^n x dx = -\cot x - x$$

$$\int \cot^n x dx = x \sin^{-1} x + \sqrt{1-x^2}$$

$$\int \cot^n x dx = x \sin^{-1} x + \sqrt{1-x^2}$$

$$\int \cot^n x dx = x \cos^{-1} x - \sqrt{1-x^2}$$

$$\int \cot^n x dx = x \cot^{-1} x + \frac{1}{2} \log (1+x^2)$$

$$\int \cot^{-1} x dx = x \cot^{-1} x + \frac{1}{2} \log (1+x^2)$$

$$\int \cot^{-1} x dx = x \cot^{-1} x + \frac{1}{2} \log (1+x^2)$$

$$\int e^{ax} dx = \frac{ea^x}{a}$$

$$e = 2.718281828459$$

 $\log_{\bullet} x = 2.3025851 \log_{10} x$

SECTION II

METALLURGICAL PRICE AND PRODUCTION STATISTICS

Metal Prices

For the current figures on metal prices it is, of course, necessary to refer to the "Engineering and Mining Journal." But it is often convenient to have the figures for some years back, for instance in computing mine valuations, or in calculations on metallurgical processes where the value of a metal over a term of years enters into the problem. For that reason I have introduced the following tables.

MONTHLY PRICES OF ELECTROLYTIC COPPER AT NEW YORK FOR THE LAST 10 YEARS (In Cents per Pound)

	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917
Jan	13.726	13.893	13.620	12.295	14.094	16.488	14.223	13.641	24.008	28.673
Feb	12.905	12.949	13.332	12.256	14.084	14.971	14.491	14.394	26.440	31.750
March	12.704	12.387	13.255	12.139	14.698	14.713	14.131	14.787	26.310	31.481
April	12.743	12.562	12.733	12.019	15.741	15.291	14.211	16.811	27.895	27.935
May	12.598	12.893	12.550	11.989	16.031	15.436	13.996	18.506	28.625	28.788
June	12.675	13.214	12.404	12.385	17.234	14.672	13.603	19.477	26.601	29.962
July	12.702	12.880	12.215	12.463	17.190	14.190	13.223	18.796	23.865	26.620
Aug	13.462	13.007	12.490	12.405	17.498	15.400	1	16.941	26.120	25.380
Sept	13.388	12.870	12.379	12.201	17.508	16.328	1	17.502	26.855	25.073
Oct	13.354	12.700	12.553	12.189	17.314	16.337	1	17.686	27.193	23.500
Nov	14.130	13.125	12.742	12.616	17.326	15.182	11.739	18.627	30.625	23.500
Dec	14.111	13.298	12.581	13.552	17.376	14.224	12.801	20.133	31.890	23.500
Year's average	13.208	12.982	12.738	12.376	16.341	15.269	13.602	17.275	27.202	27. 180

These figures from the Engineering and Mining Journal.

¹ No quotations.

AVERAGE MONTHLY PRICES OF COPPER MANUFACTURES (In Cents per Pound)

	19	11	19	012	19	13	
	Copper wire	Sheet copper	Copper wire	Sheet copper	Coppe wire	Sheet copper	
Jan. Feb M rch. April. May June July Aug. Sept. Oct. Nov. Dec. Year.	14.06 13.50 13.25 13.75 13.75 13.75 13.81 13.75 13.50 13.75 14.94	18.50 18.50 18.50 18.50 18.50 18.50 18.50 18.50 18.63 19.13	15.75 15.25 16.03 17.06 17.30 18.68 19.13 19.13 19.13 19.13 19.13	19.50 19.50 20.30 21.50 21.63 22.50 22.75 23.50 23.50 23.50 23.50	19.09 16.38 16.39 16.50 16.50 16.18 15.88 16.60 17.84 17.75 17.28 15.79	23.50 22.50 21.50 21.50 21.50 21.50 21.50 22.50 22.50 21.15 20.50	
T Cat	!	1914		1915		1916	
	Copper wire	Sheet copper	Copper	Sheet	Copper wire	Sheet	
Jan Feb	15.94 15.88	20.75 20.50	14.80 15.19	19.50 20.25	25.70 28.66	31.00 34.50	

	Copper wire	Sheet copper	Copper wire	Sheet copper	Copper wire	Sheet copper
Jan	15.94	20.75	14.80	19.50	25.70	31.00
	15.88	20.50	15.19	20.25	28.66	34.50
Feb	15.60	20.35	16.09	20.63	29.13	34.50
April	15.25	20.25	18.03	22.38	31.10	36.00
	15.23	19.90	19.95	24.50	33.75	37.88
June	15.03	19.56	21.13	25.25	32.50	38.00
July	14.88	19.38	21.63	25.50	30.25	38.00
Aug Sept	14.63	18.80	19.25	23.90	31.38	37.00
	14.34	18.00	19.34	23.50	32.00	38.00
Oct	13.34	17.38	19.28	23.50	32.35	38.00
	12.50	17.50	19.84	24.44	35.56	40.37
Nov Dec	14.25	18.88	21.81	26.00	37.00	42.00
Year	14.74	19.24	19.21	22.93	31.61	37.10
		•	<u> </u>	<u> </u>		

MONTHLY PRICES OF LEAD AT NEW YORK FOR THE LAST 10 YEARS (In Cents per Pound)

			(1n	Cents	per P	ouna)				
	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917
Jan Feb March April May June July Aug Sept Oct Nov Dec	3.725 3.838 3.993 4.253 4.466 4.447 4.580 4.515 4.351 4.330	4.018 3.986 4.168 4.287 4.350 4.321 4.363 4.342 4.341 4.370	4.613 4.459 4.376 4.315 4.343 4.404 4.400 4.400 4.422	4.440 4.394 4.412 4.373 4.435 4.499 4.500 4.485 4.265 4.298	4.026 4.073 4.200 4.194 4.392 4.720 4.569 5.048 5.071 4.615	4.325 4.327 4.381 4.342 4.325 4.624 4.698 4.402 4.293	4.048 3.970 3.810 3.900 3.900 3.875 3.828 3.528 3.683	3.827 4.053 4.221 4.274 5.932 5.659 4.656 4.610 4.600 5.155	6.246 7.136 7.630 7.463 6.936 6.352 6.244 6.810 7.000 7.042	8.636 9.199 9.288 10.207 11.171 10.710 10.594 8.680 6.710 6.249
Year's average										

These figures from the Engineering and Mining Journal.

MONTHLY PRICES OF SILVER AT NEW YORK FOR 10 YEARS (In Cents per Fine Ounce)

	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917
Jan	55.678	51.750	52.375	53.795	56.260	62.938	57.572	48.855	56.775	75.630
Feb	56.000	51.472	51.534	52.222	59.043	61.642	57.506	48 477	56.755	77.585
March	55.365	50.468	51.454	52.745	58.375	57.870	58.067	50.241	57.935	73.861
April	54.505	51.428	53.221	53.325	59.207	59.490	58.519	50.250	64.415	73.875
May	52.795	52.905	53.870	53.308	60.880	60.361	58.175	49.915	74.269	74.745
June	53.663	52.538	53.462	53.043	61.290	58.990	56.471	49.034	65.024	76.971
July	53.115	51.043	54.150	52.630	60.654	58.721	54.678	47.519	62.940	79.010
Aug	51.683	51.125	52.912	52.171	61.606	59.293	54.344	47.163	66.083	85.407
Sept	51.720	51.440	53.295	52.440	63.078	60.640	53.290	48.680	68.545	100.740
Oct	51.431	$\overline{50.923}$	55.490	53.340	63.471	60.793	50.654	49.385	67.855	87.332
Nov	49.647	50.703	55.635	55.719	62.792	58.995	49.082	51.714	71.604	85.891
Dec	48.769	52.226	54.428	54.905	63.365	57.760	49.375	54.971	75.765	85.960
Year's average	52.864	51.502	53.486	53.304	60.835	59.791	54.811	49.684	65.661	81.417

Note.—Silver in New York is sold by the fine ounce, 999, in London by the standard ounce, 925 fine.

Average Prices of Aluminum, Quicksilver, Antimony and Platinum for the Last 12 Years

	Alumi- num, cents per pound	dollars	silver, per flask 75 lb.)	Antii pe	Plati- num, dollars		
•	No. 1	San Francisco	N. Y.	Cook- son's	Hal- letts'	Ordi- naries	per ounce
1906	35.75	39.46	40.90	22.78	21.94	$\begin{vmatrix} 21.73 \end{vmatrix}$	28.04
1907	41.51	39.60	41.50	16.97	15.53	14.84	26.18
1908	31.00	44.17	44.84	8.70	8.42	8.00	22.62
1909	22.40	45.45	46.30	8.30	8.02	7.47	24.87
1910	22.85	46.51	47.06	8.25	7.88	7.39	32.70
1911	20.07	46.01	46.54	8.59	8.16	7.54	43.12
1912	22.01	42.05	42.49	8.90	8.26	7.76	45.55
1913	23.64	39.28	39.54	8.73	8.22	7.52	44.88
1914	18.63	48.68	48.31	10.732		8.76	45.14
1915	33.98	81.23	87.01			40.06	47.13
1916	60.71	125.25	125.49			25.37	83.40
1917	51.59	104.36	106.30			20.69	102.82
(D) (Ab a Marair	! - -			L	

These figures from the Engineering and Mining Journal.

MONTHLY PRICES OF SPELTER AT ST. LOUIS FOR THE LAST 10 YEARS.

(In	Cents	ner	Pou	(ba
\ 4 44	Cuw		1 VU	

	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917
Jan	4.363	4.991	5.951	5.302	6.292	6.854	5.112	6.211	16.745	9.44
Feb	4.638	4.739	5.419	5.368	6.349	6.089	5.228	8.255	18.260	9.87
Mar	4.527	4.607	5.487	5.413	6.476	5.926	5.100	8.366	16.676	10.130
Apr	4.495	4.815	5.289	5.249	6.483	5.491	4.963	9.837	16.525	9.289
May	4.458	4.974	5.041	5.198	6.529	5.256	4.924	14.610	14.106	9.19
June	4.393	5.252	4.978	5.370	6.727	4.974	4.850	21.038	11.582	9.20
July	4.338	5.252	5.002	5.545	6.966	5.128	4.770	18.856	8.755	8.47
Aug	4.556	5.579	5.129	5.803	6.878	5.508	5.418	12.611	8.560	8.19
Sept	4.619	5.646	5.364	5.719	7.313	5.444	5.230	13.270	8.820	7.96
Oct	4.651	6.043	5.478	5.951	7.276	5.188	4.750	12.596	9.659	7.813
Nov	4.909	6.231	5.826	6.223	7.221	5.083	4.962	15.792	11.422	7.672
Dec	4.987	6.099	5.474	6.151	7.081	5.004	5.430	15.211	10.495	7.510
Year's average	4.578	5.352	5.370	5.608	6.799	5.504	5.061	13.054	12.634	8.730

MONTHLY PRICES OF TIN AT NEW YORK FOR THE LAST 10 YEARS

	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917
Jan	27.380	28.060	32.700	41.255	42.529	50.298	37.779	34.260	41.825	44.175
Feb	28.978	28.290	32.920	41.614	42.962	48.766	39.830	37.415	42.717	51.420
Mar	30.577	28.727	32.403	40.157	42.577	46.832	38.038	48.426	50.741	54.388
Apr	31.702	29.445	32.976	42.185	43.923	49.115	36.154	47.884	51.230	55.910
May	30.015	29.225	33.125	43.115	46.053	49.038	33.360	38.790	49.125	63.173
June	28.024	29.322	32.769	44.605	45.815	44.820	30.577	40.288	42.231	62.053
July	29.207	29.125	32.695	42.406	44.519	40.260	31. 7 07	37.423	38.510	62.570
Aug	29.942	29.966	33.972	43.319	45.857	41.582	(a)	34.389	38.565	62.681
Sept	28.815	30.293	34.982	39.755	49.135	42.410	32.675	33.125	38.830	61.542
Oct	29.444	30.475	36.190	41.185	50.077	40.462	30.284	33.080	41.241	61.581
Nov	30.348	30.869	36.547	43.125	49.891	39.810	33.304	39.224	44.109	74.740
Dec	29.144	32.913	38.199	44.655	49.815	37.635	33.601	38.779	42.635	87.120
Year's average	29.465	29.725	34.123	42.281	46.096	44.252	34.300	38.590	43.480	61.802

These figures from the Engineering and Mining Journal.
(a) No quotations.

Metal Production Figures .

For the latest production figures the reader is referred to the annual statistical number of the Engineering and Mining Journal and to the "Mineral Industry." However, despite the fact that the following figures are somewhat out of date they are offered as useful guides.

PRODUCTION OF METALS IN THE UNITED STATES¹

Metal	Unit	1915	1916	1917
Copper (a) Ferromanganese Gold (b) Iron Lead (c) Nickel (e) Quicksilver Silver (b) Zinc (d)		1,423,698,160 226,957 101,035,700 29,916,213 535,922 44,139,826 (f) 21,033 67,485,600 492,495	39,434,797 592,241 72,611,492 74,414,802	84,456,600 38,367,853 580,464 56,807.613

(a) Production from ore originating in the United States. (b) The statistics for 1912 and 1913 are the final and those for 1914 are the preliminary statistics reported jointly by the directors of the Mint and the U. S. Geological Survey. (c) Production of refined lead ore and scrap originating in the United States: antimonial lead is included. (d) Total production of smelters, except those treating dross and junk exclusively; includes spelter derived from imported ore. (e) Imports; for 1914, first 10 months only. This nickel is refined in the United States for the production of metal, oxide and salts. (f) As reported by U. S. Geological Survey. (g) As reported by the Metallgesellschaft, Frankfurt am Main. (h) Estimated.

PRODUCTION OF MINERAL AND CHEMICAL SUBSTANCES

Substance	`Unit	1914	1915	1916
Arsenic	Short tons Short tons Short tons Long tons	8,651,940 90,821,507 422,703,970 34,555,914 31,776,670 42,911,897	88,912,000 432,500,000 41,600,000	88,500,000 509,000,000

(a) The coal and coke statistics are the estimates of Coal Age.

1 As tabulated in the Engineering and Mining Journal, Jan. 9, 1915.

WORLD'S PRODUCTION OF NICKEL (In Metric Tons)

CUITO I OLIB)		
1911	1912	1913
15,000	21,000	23,000
	5,200	5,500
		4,500
1.200		1,500
1,000	1,200	2,500
26,700	33,100	37,000
	1911 15,000 4,500 5,000 1,200 1,000	15,000 21,000 4,500 5,200 5,000 4,000 1,200 1,700 1,000 1,200

World's Production of Quicksrlver (In Metric Tons)

	1911	1912	1913
United States: a. California (a)	578	701	578
b. Texas	116 } 37 }	154	136
United States Spain (b)	731	855 1256	714 1246
Austria-Hungary	793 931	783 986	855 1004
Italy Mexico (estimated)	150	150	150
Total	4100	4030	3969

(a) Eng. and Min. Journ. (b) Exports.

World's Consumption of Aluminum

(In Metric Tons)
(From statistical report of the Metallgesellschaft, Frankfurt am Main)

	1911	1912	1913
United States (a)	20,900	29,800	32,800
France	. ,	6,000	7,000
England	. ,	4,000	5,000
Italy	. ,	1,000	1,000
Other countries		22,100	21,000
Totals	46,800	62,900	66,800

(a) U. S. Geological Survey.

World's Production of Aluminum

(In Metric Tons)
(From statistical report of the Metallgesellschaft, Frankfurt am Main)

	1911	1912	1913
United States	18,000	19,500	22,500
Canada (exports)		8,300	5,900
Austria-Hungary	8,000	12,000	12,000
France	10,000	13,000	18,000
England	5,000	7,500	7,500
[taly			800
Norway	900	1,500	1,500
Totals	45,000	62,600	68,200

No reliable foreign statistics for 1914 et seq.

WORLD'S PRODUCTION OF PIG LEAD
(In Metric Tons)
(From statistical report of the Metallgesellschaft, Frankfurt am Main)

	1911	1912	1913
$\operatorname{Spain}(a)$	175,100	186,700	203,000
Germany	164,400	176,600	181,100
France	23,600	31,100	(c)28,000
Great Britain	26,000	29,200	30,500
Belgium	44,300	51,200	50,800
Italy	16,700	21,500	21,700
Austria-Hungary	19,600	21,400	24,100
Greece	14,300	14,500	18,400
Sweden and Norway	1,100	1,300	1,500
Russia	1,000	(c)1,000	(c)1,000
Asiatic Turkey	12,400	12,500	13,900
Total Europe (b)	498,500	547,000	574,000
United States	377,900	387,300	407,800
Mexico	124,600	(c)108,000	(c)62,000
Canada	10,700	16,300	17,100
Total North America	513,200	511,600	486,900
Japan	4,200	3,600	(c)3,600
Australia	99,600	107,400	116,000
Other countries	20,500	12,200	6,200
Total world's production	1,136,000	1,181,800	1,186,700

(a) Exports. (b) Including Asiatic Turkey. (c) Estimated.

PRODUCTION OF LEAD (REFINERY STATISTICS)¹ (a) (In Tons of 2000 Lb.)

Domestic:	1913	1914	1915	1916	1917
Desilverized Antimonial S. E. Missouri. S. W. Missouri.	261,616	318,697	305,160	330,189	317,952
	16,345	17,177	24,601	22,819	17,068
	133,203	177,413	185,849	206,105	204,869
	22,312	25,448	20,312	33,128	40,575
Totals Foreign:	433,476	538,735	535,922	592,241	580,464
Desilverized Antimonial	54,774	28,475	43,301	17,832	49,213
	2,300	1,119	2,883	3,304	1,858
TotalsGrand totals	57,074	29,594	46,184	21,136	51,071
	490,550	568,329	582,106	613,377	631,535

As reported by the Engineering and Mining Journal.

(a) These figures include the lead derived from scrap and junk by primary smelters.

WORLD'S CONSUMPTION OF LEAD
(In Metric Tons)
(From statistical report of the Metallgesellschaft, Frankfurt am Main)

	1911	1912	1913
Germany	232,900	232,100	223,500
Great Britain	198,300	196,300.	191,400
France	99,600	104,700	107,600
Russia	42,900	45,600	58,800
Belgium	43,000	44,900	42,900
Italy	36,300	33,000	32,600
Austria-Hungary	36,200	37,800	35,500
Holland (a)	6,800	6,300	9,500
Switzerland	5,000	6,400	5,800
Other European countries	3,500	4,400	6,300
Total Europe	704,500	711,500	713,900
United States	364,400	398,400	401,300
Canada	21,100	30,000	22,900
Japan	18,900	21,800	(a)18,500
Australia	9,100	10,100	9,600
Other countries	31,200	30,000	(a)30,000
Total world's consumption	1,149,200	1,201,800	1,196,200

(a) Estimated.

World's Production of Spelter
(In Metric Tons)
(From statistical report of the Metallgesellschaft, Frankfurt am Main)

	1911	1912	1913
Germany			
Rheinland-Westphalia	81,458	86,619	92,852
Silesia	156,174	169,088	170,119
Other districts	12,761	15,357	20,142
Belgium	195,092	200,198	197,703
Holland	22,733	23,932	24,323
Great Britain	66,956	57,231	59,146
France and Spain	64,221	72,161	71,023
Austria and Italy	16,876	19,604	21,707
Russia	9,936	8,763	7,610
Norway	6,680	8,128	9,287
Sweden			
Europe	632,887	661,081	673,912
United States	267,472	314,512	320,283
Australia	1,727	2,296	3,724
Total	902,100	977,900	997,900

ZINC-SMELTING CAPACITY OF THE UNITED STATES¹ (Number of Retorts at End of Years)

(Number of Reto	orts at End of Years)		
Name	Situation	1916	1917
American Spelter Co. (a)	Pittsburg, Kan.	(b) 896	(b) 896
American Steel & Wire Co	Donora, Penn.	9,120	
American Zinc and Chem. Co. (a)	Langeloth, Penn.	7,296	
American Zinc Co. of Ill	Hillsboro, Ill.	4,864	
American Zinc, Lead and Smg. Co. (a)	Dearing, Kan.	4,480	
American Zinc, Lead and Smg. Co. (a)	Caney, Kan.	6,080	
American Zinc, Lead and Smg. Co.	Cancy, Itali.	0,000	0,000
(c) (a)	Neodesha, Kan.	3,760	3,760
American Zinc, Lead and Smg. Co. (c).		4,864	
Arkansas Zinc and Smelting Corpn	Van Buren, Ark.	2,400	
Athletic Min. and Smelting Co	Fort Smith, Ark.	(d)	1,664
Bartlesville Zinc Co	Bartlesville, Okla.	7,488	5,184
Bartlesville Zinc Co	Blackwell, Okla.	8,800	
Darlesville Zine Co	Collinsville, Okla.	13,440	
Bartlesville Zinc Co	Commisvine, Okia.	10,240	10,440
Bartlesville Zinc Co., Lanyon-Starr	Ranticaville Olde	2 456	2 450
Branch	Bartlesville, Okla.	3,456	
Chanute Spelter Co. (a)	Chanute, Kan.	1,280	
Collinsville Zinc Co. (a)	Collinsville, Ill.	1,984	(b) 1,984
Eagle-Picher Lead Co	Henryetta, Okla.	3,000	(6)3,000
Edgar Zinc Co	Carondelet, Mo.	2,000	
Edgar Zine Co	Cherryvale, Kan.	4,800	
Fort Smith Spelter Co	Forth Smith, Ark.	2,560	
Grasselli Chemical Co	Clarksburg, W. Va.	5,760	
Grasselli Chemical Co	Meadowbrook, W. Va.		
Grasselli Chemical Co	Terre Haute, Ind.	(d)	3,360
Hegeler Zinc Co	Danville, Ill.	5,400	
Henryetta Spelter Co	Henryetta, Okla.	3,000	(a)3,000
Illinois Zine Co	Peru, Ill.	4,640	(b)4,640
Iola Zine Co. (h)	Concreto, Kan.	(b) 660	
Joplin Ore and Spelter Co	Pittsburg, Kan.	(j) 1,792	
J. B. Kirk Gas and Acid Co. (a)	Iola, Kan.	3,440	
Kusa Spelter Co	Kusa, Okla.	3,720	7,520
La Harpe Spelter Co	Kusa, Okla.	4,000	(k)
Lanyon Smelting Co	Pittsburg, Kan.	448	
Robert Lanyon Zinc and Acid Co	Hillsboro, Ill.	3,200	(b) 3,200
Lanyon-Starr Smelting Co. (e)	T - C-11- TH		0 100
Matthiessen & Hegeler Zinc Co	La Salle, Ill.	6,168	6,168
Mineral Point Zinc Co	Depue, Ill.	9,068	
Missouri Zinc Smelting Co (a)	Rich Hill, Mo.	(j) 448	
National Zinc Co	Bartlesyille, Okla.	4,970	4,256
National Zinc Co	Springfield, Ill.	3,800	4,480
Nevada Smelting Co	Nevada, Mo.	672	(b) 672
New Jersey Zinc Co. of Penn	Palmerton, Penn.	7,200	7,200
Oklahoma Spelter Co	Kusa, Okla.	(j) 1,600	
Owen Spelter Co	Caney, Kan.	1,920	
Pittsburg Zine Co	Pittsburg, Kan.	910	
Prime Western Spelter Co	Gas City, Kan.	4,866	
Quinton Spelter Co	Quinton, Okla.	1,340	
Sandoval Zinc Co	Sandoval, Ill.	672	
Tulsa Fuel and Manufacturing Co	Collinsville, Okla.	6,232	
United States Smelting Co. (a)	Altoona, Kan.	4,600	4,640
United States Smelting Co	Checotah, Okla.	4,480	
United States Smelting Co	La Harpe, Kan.	1,926	
United States Zinc Co. (1)	Henryetta, Okla.	1,200	
United States Zinc Co	Sand Springs, Okla.	8,000	
United States Zinc Co	Pueblo, Colo.	1,984	2,200
United Zine Smelting Corpn	Moundsville, W. Va.	(d)	(m) 1,728
United Zine Smelting Corpn. (i)	Clarksburg, W. Va.	3,648	
Weir Smelting Co	Weir, Kan.	448	(a) 448
Totale		010.014	017 104
Totals		212,614	217,194
1 As removed by the Pagingania			-

1 As reported by the Engineering and Mining Journal.

(a) Closed during latter part of 1917. (b) No report received; entered the same as previous year. (c) Formerly Granby Mining and Smelting Co. (d) Under construction. (e) See Bartlesville Zinc Co. (g) Dismantled, end of 1917.

(h) Idle all of 1917. (i) Formerly Clarksburg Zinc Co. (j) Idle latter part of 1916. (k) Absorbed by Kusa Spelter Co. (l) Formerly Western Spelter Co. (m) Not yet in operation.

PRODUCTION OF SPELTER¹ (In Tons of 2000 Lb.)

(By Ore Smelters Only (b))

States	1913	1914	1915	1916	1917
Arkansas Colorado Illinois Missouri-Kansas Oklahoma Electrolytic East and others (a) Totals	8,637 111,551 85,157 83,230 69,687	130,587 53,424 92,467 85,682	161,665 111,052 111,405	181,495 154,396 169,064 10,963 147,555	8,488 176,106 86,227 204,720 29,451 154,729

⁽a) Includes some works that smelt dross and scrap as well as ore, but does not include works that smelt dross and scrap only. Discrepancies among statistical reports of the spelter production of the United States arise largely on account of the difference in the dividing line that is drawn in this respect. (b) Includes Anaconda and other electrolytic production in 1915.

AMERICAN SILVER-LEAD SMELTING WORKS¹

American Smelting and Refining Co Cons. Kansas City Sm. and Ref. Co Bunker Hill & Sullivan Min. and Concentrating Co Selby Smelting and Lead Co Cohio & Colorado Smelting Co Northport Smelting and Refining Co Northport Smelting and Refining Co International Smelting Co Totals, United States. Totals, United States. Totals, United States. American Smelting and Refining Co American Smelting Smelting Co American Smelting American Smelting American Smelting Ame	nnual pacity (a)
American Smelting and Refining Co Cons. Kansas City Sm. and Ref. Co Bunker Hill & Sullivan Min. and Concentrating Co Selby Smelting and Lead Co United States Smelting Co Northport Smelting Co Northport Smelting and Refining Co International Smelting Co International Smelting Co Tooele, Utah Tooele, Utah American Smelting and Refining Co American Smelting Sco Selby, Calif. Salida, Colo. Midvale, Utah Northport, Wash. Carnegie, Penn. Tooele, Utah Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes Chihuahua 7 Aguascalientes	510,000
American Smelting and Refining Co Cons. Kansas City Sm. and Ref. Co Bunker Hill & Sullivan Min. and Concentrating Co Selby Smelting and Lead Co Ohio & Colorado Smelting Co Northport Smelting Co Northport Smelting and Refining Co International Smelting Co International Smelting Co Tooele, Utah Tooele, Utah American Smelting and Refining Co American Smelting American Smelting American	380,000
American Smelting and Refining Co Cons. Kansas City Sm. and Ref. Co Bunker Hill & Sullivan Min. and Concentrating Co Centrating Co Selby Smelting and Lead Co Cohio & Colorado Smelting Co Northport Smelting and Refining Co Northport Smelting and Refining Co International Smelting Co International Smelting Co American Smelting and Refining Co American Smelting Co	210,000
American Smelting and Refining Co American Smelting and Refining Co American Smelting and Refining Co Cons. Kansas City Sm. and Ref. Co Bunker Hill & Sullivan Min. and Concentrating Co Centrating Co Selby Smelting and Lead Co Chio & Colorado Smelting Co Northport Smelting and Refining Co Northport Smelting and Refining Co International Smelting Co International Smelting Co Totals, United States. American Smelting and Refining Co American Smelting American Smelting Co American Smelting American Smelting Co American	510,000
American Smelting and Refining Co American Smelting and Refining Co Cons. Kansas City Sm. and Ref. Co Bunker Hill & Sullivan Min. and Concentrating Co Selby Smelting and Lead Co Ohio & Colorado Smelting Co United States Smelting Co Northport Smelting and Refining Co International Smelting Co International Smelting Co Totals, United States. American Smelting and Refining Co American Smelting American Smelting American Smelting American Smelting American	357,000
American Smelting and Refining Co Cons. Kansas City Sm. and Ref. Co Bunker Hill & Sullivan Min. and Concentrating Co Selby Smelting and Lead Co Ohio & Colorado Smelting Co United States Smelting Co Northport Smelting and Refining Co International Smelting Co International Smelting Co International Smelting and Refining Co American Smelting American	306,000
Cons. Kansas City Sm. and Ref. Co Bunker Hill & Sullivan Min. and Concentrating Co Selby Smelting and Lead Co Ohio & Colorado Smelting Co United States Smelting Co Northport Smelting and Refining Co Pennsylvania Smelting Co International Smelting Co Totals, United States. Totals, United States. Totals, United States. American Smelting and Refining Co American Smelting a	82,000
Bunker Hill & Sullivan Min. and Concentrating Co	70,000
centrating Co	380,000
Selby Smelting and Lead Co	
Selby Smelting and Lead Co	300,000
Ohio & Colorado Smelting Co	210,000
Northport Smelting and Refining Co Pennsylvania Smelting Co International Smelting Co Totals, United States American Smelting and Refining Co Chihuahua 7 Velardeña Compañia Metalurgica Mexicana Compañia Metalurgica de Torreon Northport, Wash. Carnegie, Penn. 7 Monterrey Aguascalientes Chihuahua 7 Velardeña 3 San Luis Potosi (c) 8	345,000
Northport Smelting and Refining Co Pennsylvania Smelting Co International Smelting Co Totals, United States American Smelting and Refining Co Compafia Metalurgica Mexicana Compafia Metalurgica de Torreon Northport, Wash. Carnegie, Penn. 78 5,7 Monterrey Aguascalientes Chihuahua 7 Velardeña 3 San Luis Potosi (c) 10 Torreon	30,000
Totals, United States	216,000
Totals, United States	60,000
American Smelting and Refining Co American Smelting and Refining Co Aguascalientes American Smelting and Refining Co Chihuahua American Smelters Securities Co Velardeña Compañia Metalurgica Mexicana San Luis Potosi (c) Compañia Metalurgica de Torreon Torreon	300,000
American Smelting and Refining Co Aguascalientes American Smelting and Refining Co Chihuahua 7 American Smelters Securities Co Velardeña Compañia Metalurgica Mexicana San Luis Potosi (c) Compañia Metalurgica de Torreon Torreon 8	766,000
American Smelting and Refining Co Aguascalientes American Smelting and Refining Co Chihuahua 7 American Smelters Securities Co Velardeña Compañia Metalurgica Mexicana San Luis Potosi (c) Compañia Metalurgica de Torreon Torreon 8	584,000
American Smelting and Refining Co Chihuahua American Smelters Securities Co Velardeña Compañia Metalurgica Mexicana San Luis Potosi (c) Compañia Metalurgica de Torreon Torreon 8	40,000
American Smelters Securities Co Velardeña Compañia Metalurgica Mexicana San Luis Potosi (c) Compañia Metalurgica de Torreon Torreon 8	100,000
Compañia Metalurgica Mexicana San Luis Potosi (c) 10 Compañia Metalurgica de Torreon Torreon 8	50,000
Compañia Metalurgica de Torreon Torreon 8	250,000
	360,000
· · · · · · · · · · · · · · · · · · ·	325,000
Totals, Mexico	109,000
Consolidated Mining and Smelting Co. Trail, B. C. 4	140,000

⁽a) Tons of charge. (b) Smelt chiefly refinery between-products. being operated, but plant is expected to start in the near future.

1 Engineering and Mining Journal, Jan. 12, 1918. (c) Not

WORLD'S CONSUMPTION OF COPPER
(In Metric Tons)
(From statistical report of the Metallgesellschaft, Frankfurt am Main)

Europe	1911	1912	1913
Germany	222,500	231,700	259,300
Great Britain	159,100	144,700	140,300
France	95,700	98,500	103,600
Austria-Hungary	38,500	48,200	39,200
Russia	32,800	40,000	40,200
<u>Italy</u>	29,400	34,200	31,200
Belgium	13,500	15,000	15,000
Netherlands	1,000	1,000	1,000
Other European countries	10,000	10,200	(a)13,300
Total consumption in Europe America	602,500	623,500	643,100
United States	321,900	371,800	348,100
Others in America	3,000	3,000	3,000
Total consumption in America Asia, Australia, Africa Production Japan and Aus-	324,900	374,800	351,100
tralia	95,000	111,900	119,000
Imports from Europe	500	1,400	1,000
Imports from America		500	80
Total Exports to Europe and Amer-	95,500	113,800	120,100
ica	68,800	73,400	69,800
Consumption in Asia, Australia and Africa	26,700	40,400	50,300
World's consumption	954,100	1,038,700	1,044,500
World's production	893,800	1,018,600	1,005,900

⁽a) Estimated.

64 METALLURGISTS AND CHEMISTS' HANDBOOK

WORLD'S PRODUCTION OF COPPER (a)

(In Metric Tone)

Country	1914	1915	1916	1917
United States Mexico Canada Cuba Australasia Peru Chile Bolivia Japan Russia Germany Africa Spain and Portugal Other Countries	525,529 36,337 34,027 6,251 37,592 27,090 40,876 1,306 (c) 71,046 32,262 (b) 30,480 24,578 (b) 37,099 (b) 25,176	646,212 30,969 47,202 8,836 32,512 (f) 32,410 47,142 (e) 3,000 (c) 76,039 25,881 (e) 35,000 27,327 (e) 46,200 (e) 25,000	881,237 55,128 47,985 7,816 35,000 (f) 41,625 64,636 (e) 4,000 (c) 101,467 20,887 (e) 45,000 34,572 (e) 42,000 (e) 25,000	856,570 43,827 50,351 9,622 38,100 (f) 45,620 (g) 75,345 (e) 4,000 (g) 124,306 (e) 16,000 (e) 45,000 (e) 37,315 (e) 42,000 (e) 25,000
Totals	929,649	1,083,730	1,406,353	1,413,056

⁽a) The statistics in this table are Engineering and Mining Journal compilations, except where specially noted to the contrary. (b) As reported by Henry R. Merton & Co. (c) As officially reported. (d) Privately communicated to us from Japan. (g) Estimated on basis of nearly complete reports.

SMELTERS' PRODUCTION OF COPPER IN THE UNITED STATES¹

(In Pounds)

1914 24,285,000 87,978 852 29,515,488 10,104,579 4,850,460 57,089,795	444,089,147 37,935,893 8,126,000 5,502,000	9,802,183 6,741,001	91,918,000 692,923,722 46,881,089 12,028,000 5,020,000
87,978 852 29,515,488 10,104,579 4,856 460	444,089,147 37,935,893 8,126,000 5,502,000	892,630,280 81,358,334 9,802,183 6,741,001	692,923, 722 46,881, 089 12,028, 000 5,030, 000
29,515,488 10,104,579 4.856 460	444,089,147 37,935,893 8,126,000 5,502,000	81,358,334 9,802,183 6,741,001	692,923, 722 46,881, 089 12,028, 000 5,030, 000
10,104,579 4,856 460	8,126,000 5,602,000	9,802,183 6,741,001	46,881,0 89 12,028,000 5,020, 000
4.856 460	8,126,000 5,602,000	9,802,183 6,741,001	5,020,000
	5,602,000	6,741,001	5,020,000
57 089 795			
0110001100	241,120,104	270,058,601	273,445,747
43,139,737		351,995,058	
60,078,095			103 719,442
64.338.892		83 013.805	
53.555 902		225,396,808	244,398,684
165,023		(a)	(a)
19,213,965	18.858.677	20,018,261	23,692,274
58.581.876	1,423,698,160	1,942,776,309	1,858,395,945
100	53.555.902 165,023 19,213,965 4,257,088	53.555.902 165,023 19,213,965 4,257,088 (a) 18,858,677 (b) 4,452,420	53.555.902 180,951,174 225,390,808 165,023 (a) (a) (a) 19,213,965 18,858,677 20,018,261 4,257,088 (b) 4,452,420 (b) 15,685,226

As reported by the Engineering and Mining Journal.

(a) Included in "Other States."

(b) Includes copper originating in states other than those enumerated and also copper whose origin could not be correctly distributed at this early date. Indeed, the distribution for 1916 in several cases in this table must be regarded as merely provisional. Thus, Utah is undoubtedly credited with more or less copper that belongs to Idaho and Nevada.

SMELTERS' PRODUCTION—(Continued)

Source	1914	1915	1916	1917
North American ore Foreign ore	1,327,488,479	1,612,450,828	2,187,328,864	2,117,235,708
	50,101,308	44,749,105	73,391,517	76,078,047
	20,894,559	29,827,203	37,380,759	38,854,053
Totals To foreign refiners	1,398,484,346	1,687,027,136	2,298,101,140	2,219,066,922
	36,765,920	39,734,120	38,423,577	33,266,348
To American refiners	1,361,718,426	1,647,293,016	2,259,677,563	2,198,901,460
Crude copper imported.	131,125,076	140,415,341	152,770,536	(a)281,211,588
Total crude copper	1,492,843,502	1,787,708,357	2,412,448,099	2,480,113,048

⁽a) Estimated on basis of nine months' returns.

WORLD'S PRODUCTION OF SILVER
Smelters' Production—In Metric Tons
(From statistical report of the Metallgesellschaft, Frankfurt am Main)

	1911	1912	1913
Great Britain	536.1	499.3	395.1
Germany	420.0	476.0	537 .9
Belgium	264.7	252.7	280.0
Spain and Portugal	· 134.9	117.6	(a)130.0
France	53.0		
Austria-Hungary	63.1		, , ,
Italy	14.2		
Norway	7.2		
Russia	4.9		\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \
Turkey (a)	$\overline{1.5}$		V -
Sweden	2.0	1.2	
			,
Total Europe	1499.6	1481.2	1478.7
United States	3891.9	4073.0	4059.1
Mexico		b1063.2	b1159.2
Central and South America (a)	200.0		
Canada	509.2		
Total America	5656.7	5929.6	5974.8
Asia (Japan)	141.6	138.1	148.9
Australia	129.1	136.4	143.0
Total production	7427.0	7685.3	7745.4

⁽a) Estimated. (b) Fiscal years 1910-1911 and 1911-1912.

66 METALLURGISTS AND CHEMISTS' HANDBOOK

SILVER PRODUCTION IN THE UNITED STATES (In Fine Ounces)

State	1915	1916	1917
Alaska	1,054,634	1,266,317	1,351,100
Arizona	5,665,672	6,680,252	8,183,200
California	1,689,924	1,936,910	1,989,800
Colorado		7,551,761	8,163,600
Georgia	141	1	
Idaho	13,042,466	11,570,399	11,683,100
Illinois	3,892	5,782	3,300
Maryland	100	153	1,100
Michigan	581,874	759,068	686,700
Missouri	55,534	128,860	21,100
Montana		14,046,054	13,711,100
Nevada	14,453,085	13,682,067	11,441,000
New Hampshire		935	
New Mexico	2,337,064	1,729,917	1,313,700
North Carolina	1,496	1,738	2,800
Oklahoma		.606	,
Oregon	125,499	221,887	215,700
South Carolina]	
South Dakota	197,569	210,100	191,100
Tennessee	99,171	93,837	99,300
Texas	724,580	664,319	583,200
\mathbf{Utah}	13,073,471	13,545,802	14,315,300
Virginia	• • • • • • • • • • •	508	9,400
Vermont	150	1,964	400
Washington	213,877	294,516	257,000
Wyoming	2,910	3,407	4,900
Continental U.S	74,945,927	74,397,159	74,227,900
Philippines	15,148	17,643	16,600
Porto Rico			•••••••
Total	74,961,075	74,414,802	74,244,500

As reported by the Director of the Mint and the U.S. Geological Survey.

GOLD PRODUCTION OF THE WORLD FOR 21 YEARS1

1895	\$198,995,741	1905	\$378 411 054
	211,242,081	1906	
	237,833,984	1907	
	287,327,833	1908	
_	311,505,947		
	258,829,703	1910	
	260,877,429	1911	
1902	298,812,493	1912	
1903	329,475,401		
1904	349,088,293	1914	451,582,129
	1915	473,124,590	

As tabulated in the Engineering and Mining Journal, Jan. 10, 1914.

GOLD PRODUCTION OF THE WORLD

	1912	1913	1914
Transvaal	\$188,599,260	\$181,889,012	\$173,176,133
Rhodesia	13,166,230	13,935,681	17,745,980
West Africa	7,386,028	l	8,671,371
Madagascar, etc	2,925,000		
Total Africa	\$212,076,518	\$205,715,653	\$201,573,484
United States	\$93,451,500	\$88,884,400	94,531,800
Mexico	22,500,000		
Canada	12,559,288	1	
Central America, etc	3,632,500		1
Total North America.	\$132,143,288	\$ 128,630,931	\$ 132,141,844
Russia, inc. Siberia	\$27,635,500	1 ' '	1
France	1,847,000		
Other Europe	3,615,000		1
Total Europe	\$33,097,500	\$ 34,262,100	\$30,563,000
British India British and Dutch E.	\$12,115,162		, ,
Indies	4,925,000	4,739,100	4,690,000
Japan and Chosen	7,165,000		
China and others	3,750,000		l
Total Asia, not inc. Siberia	\$27,955,162	\$27,969,083	\$28,119,480
South America	\$12,425,000	\$ 13,058,400	\$ 13,525,000
Australasia	56,635,800	[" / <u> / </u>	l - T
Total for the world	\$474,333,268	\$4 62,669,558	\$ 451,582,1 29

Official returns of the various countries and reports of the Director of the U.S. Mint.

GOLD PRODUCTION IN THE UNITED STATES (Values)

	(v aiues)	T	
State	1915	1916	1917
Alabama	\$5,100	\$7,400	\$4,200
Alaska	16,710,000	16,124,800	15,171,300
Arizona		4,092,800	5,533,800
California	22,547,400	21,980,400	20,815,900
Colorado		19,185,000	15,955,100
Georgia	34,800	20,400	6,000
Idaho		1,058,300	711,500
Maryland			100
Montana	4,978,300	4,328,400	3,756,500
Nevada	11,883,700	9,064,700	6,922,900
New Mexico	1,460,100	1,350,000	1,025,100
North Carolina		23,000	15,700
Oregon	1,867,100	1,901,500	1,677,400
South Carolina	3,600	300	1,100
South Dakota	7,403,500	7,471,700	7,392,600
Tennessee	6,800	5,700	5,300
Texas		500	900
Utah	3,907,900	3,859,000	3,620,300
Vermont		300	
Virginia		500	1,700
Washington	461,600	580,600	434,900
Wyoming	13,900	20,200	200
Continental U.S	\$99,714,100	\$91,075,500	\$83,052,500
Philippines	1,320,900	1,514,200	1,404,000
Porto Rico	700	600	100
Totals	\$101,035,700	\$92,590,300	\$84,456,600

As reported by the Director of the Mint and the U.S. Geological Survey.

ESTIMATE OF WORLD'S	PRODUC	TION OF	CRUDE I	PLATINUM 1
Country	1912	1913	1914	1915
Borneo and Sumatra Canada Colombia New South Wales Russia United States	200 30 12,000 778 300,000 721 313,729	200 50 15,000 1,275 250,000 483 267,008	* 30 17,500 1,248 241,200 570 260,548	100 19,000 †56 124,000 742 143,898

^{*} No basis for estimate. † No figures from Tasmania available.

1 Estimates by U. S. Geological Survey.

U. S. Pig Iron Production for 15 Years¹ (In Long Tons) .

U. S. Iron Ore Production and Consumption¹. (In Long Tons)

	1912	1913	1914
Lake Superior shipments Southern ore mined Eastern and other local ores.	48,211,778 7,500,000 3,485,000	7,950,000	6,175,000
Total production	59,196,778 2,104,576	61,847,116 2,594,876	42,911,897 1,455,000
Total supplies Exports	61,301,354 1,195,742	64,441,992 1,042,151	44 ,366,897 660,000
Approximate consumption.	60,105,612	63,399,841	43,706,897

PRODUCTION OF CRUDE PETROLEUM IN THE UNITED STATES¹ (In Barrels of 42 Gal.)

Field	1912	1913	1914
California	84,823,992	96,881,967	100,093,568
Colorado	200,000	220,000	(f)200,000
Texas (a)	11,778,324	15,544,046	20,586,377
Louisiana	9,791,896	12,901,703	16,860,235
Illinois	28,400,000	(e)23,893,899	21,500,000
Lima { Indiana Ohio		4,750,000	2,900,000
Mid-continental (b).	52,771,603	64,556,000	(d)97,400,000
Kentucky-Tennessee	. , .	500,000	580,000
Appalachian (c)	26,000,000	25,673,000	23,800,000
Wyoming	500,000	2,354,000	4,100,000
Others	5,000	50,000	(f)50,000
Total	218,970,815	247,321,615	288,070,180

⁽a) Includes Panhandle field of Texas. (b) Kansas and Oklahoma, only. (c) Pennsylvania, New York, West Virginia and eastern Ohio. (d) Estimate of Dr. David T. Dav, in "Oil, Paint and Drug Reporter," Jan. 2, 1915. (e) U. S. Geol. Survey. (f) Estimated.

1 As reported by the Engineering and Mining Journal.

Tin Production and Consumption (In Long Tons)

. (III DOIG TOW)	,	, , , , , , , , , , , , , , , , , , , 	
	1913	1914	1915
Exports, Straits and Malay Peninsula	62,242	61,986	66,760
Exports, Australian	3,253	1,771	2,275
Banka and Billiton sales		10,975	15,093
Chinese exports and production ¹	8,200		7,097
Bolivian exports ¹	22,719	24,844	18,800
Bolivian exports ¹	1,900		2,158
Nigerian production ¹	[• • • • • • • • • • • • • • • • • • •	1,962	1,899
Cornwall production ¹	4,900	4,500	4,000
Total	120,356	116,569	118,082
U. S. imports and consumption	45,900	42,995	49,480
Great Britain, imports and consumption	28,736	30,531	39,937
Holland, imports		15,810	7,625
Other Europe, imports	21,250	18,633	11,550
Australian consumption	1,000		1,100
China and India consumption	6,500		6,650
Totals	119,959	115,419	116,342
Visible stocks, Dec. 1	16,045	13,432	14,535

¹ Not in "Statistics."

World's Production of Tin (In Metric Tons) (From statistical report of the Metallgesellschaft, Frankfurt am Main)

•	1911	1912	1913
Straits Settlements	57,944	61,528	65,640
Great Britain:		1	
From home ores	4,950	5,338	(c)5,300
From other ores (a)	13,850	13,600	16,700
Germany (a)	11,378	11,000	(c)11,500
France	500	500	1,200
Banca (sold in Holland)	15,147	16,111	15,173
Billiton (sold in Holland and	10,11.	10,111	10,110
	2,240	2,243	2,243
Java)	,		
Australia	5,150	5,130	4,870
China (exports)	6,050	8,782	(c)6,000
Bolivia (b)	400	500	300
	117,600	124,700	128,900

⁽a) Mainly from Bolivian ores. (b) Importation of Bolivian crude tin into Great Britain. (c) Estimated. No later statistics available.

World's Consumption of Tin (In Metric Tons)

. (From statistical report of the Metallgesellschaft, Frankfurt am Main)

	1911	1912	1913
Great Britain	21,900	21,800	24,400
Germany	18,300	20,200	19,300
France	7,400	7,500	8,300
Austria-Hungary	4,000	3,800	3,200
Belgium	1,700	1,500	2,300
Russia	1,900	2,600	2,700
Italy	2,400	2,500	2,900
Switzerland	1,200	1,400	1,400
Spain	1,200	1,300	1,300
Scandinavia	1,400	1,500	1,600
Holland	(a)250	(a)250	(a)250
Other European countries	1,200	1,100	1,200
Total Europe	62,800	65,500	68,900
United States	48,000	51,700	45,000
Other America	2,300	3,300	3,400
Australia	(a)900	(a)1,200	(a)1,400
Africa	(a)500	(a)600	(a)500
China (imports)	1,993	2,427	(a)2,400
Other Asia	3,000	3,000	3,300
World's consumption	119,500	127,700	124,900
World's production	117,600	124,700	128,900

(a) Estimated. No later statistics available.

WORLD'S CONSUMPTION OF SPELTER (In Metric Tons) (From statistical report of the Metallgesellschaft, Frankfurt am Main)

	_	•	
	1911	1912	1913
United States	251,600	312,900	313,300
Germany	219,300	225,800	232,000
Great Britain	175,700	185,200	194,600
France	82,000	82,000	81,100
Belgium	73,700	77,200	76,400
Austria-Hungary	43,500	46,800	40,400
Russia	28,900	27,900	33,300
Italy	10,100	10,700	10,900
Spain	4,800	4,700	5,900
Holland (estimated)	4,000	4,000	4,000
Other countries (estimated)	17,800	19,700	20,900
Total	911,400	996,900	1,012,700

COPPER SMEI	SMELTING WORKS OF NO	North A	AMBRICA				
Сомраву	Situation of Works	No. of Blast Fur- naces	Angual	No. of Rever- bera- tory Fur- naces	Annual	No. Con- Ver ters	Annual Capacity In Ore (a)
American Smelting & Refining Co. American Smelters Securities Co. Anaconda Copper Mining Co. Compagne du Boleo Calanda Copper Mining Co. Calanda Copper Corput. Calanda Copper Corput. Calanda Copper Corput. Calanda Copper Corput. Calanda Copper Mining & Smelting Co. Calanda Copper Mining & Smelting & Power Co. East Butte Copper Mining, Smelting & Power Co. Granby Consolidated Mining, Smelting & Power Co. International Smelting Co. International Smelting Co. International Smelting Co. International Smelting Co.	Aguascalientes, Mer. Perth Amboy, N. J. Omaha, Neb. El Paso, Terras Matchuala, S.L.P., Mer. Elayden, Aris. Sagoo, Aris. Carfield, Utah Tecoma, Wash Tecoma, Wash Tecoma, Ariz. Santa Rosalia, Mont. Chiton, Ariz. Santa Rosalia, Mont. Chiton, Ariz. Santa Rosalia, Mont. Chiton, Ariz. Banta Rosalia, Mont. Chiton, Ariz. Banta Rosalia, Mer. Douglas, Ariz. Humboldt, Aris. Humboldt, Aris. Humboldt, Aris. Labbella, Tenn. Butte, Mont. Grand Forle, B. C. Tooele, Utah Miami, Aris.	0- 40 040000 r-0000-00-0004	800,000 800,000 325,000 375,000 375,000 375,000 1,250,000 1,300,000 1		435,000 435,000 144,000 144,000 330,000 330,000 163,000 100,000 275,000 700,000	4684 6884 1-88 688688888 888888	55.55.45. 9.50.00000000000000000000000000000000

AMERICA.—Concluded
North
ð
WORKS
SMELTING
COPPER

	Situation of Works	of Blast Fur Daces	Annual Capacity	Rever bera- tory Fur-	Annual Capacity	E de la se	Annual Capacity in Ore (a)
Ladysmith Smelting Corpu (f) Markmoth Copper Mining Co Markmoth Copper Mining Co Markmoth Copper Co Markmoth Copper Co Markmoth Copper Co Mountain Copper Co Neveda Consolidated Copper Co Neveda Constrain Copper Co Neveda Copper Co Norfolk Smelting Co Norfolk Mark Santa Fé Cold & Copper Mining Co Norfolk Mark Copper Co Swansen Copper Co Norfolk Mark Co Norfolk Mining Co Norfolk Mining Co Norfolk Mark Co No	h, B. C. Calif. n, Mev. on del Orc. ont. Calif. Calif. (calif. in N y. fielk, Va. in Hook, N. J. in Pueble, Mex. Cosh., Mex. N. J. in Aris	21-20 00 HHH40 HH0-10000 40-	236,250 730,000 216,000 216,000 100,000 175,000 100,000 175,000 175,000 175,000 175,000 100,000 100,000 100,000 100,000 100,000	0940 → 1 09 · · · · · · · · · · · · · · · · · ·	84,000 84,000 84,000		28,500 520,000 60,000 40,000 5,944 5,944 15,000 67,000

ELECTROLYTIC COPPER REFINERIES OF THE UNITED STATES AND CANADA

Wurks	Situation	1913 Ospacity. pounds	1914 capacity, poinde	1915 capacity, pounds*	1918 capacity, pounds	1917 capacity, pounds*
Nichols Copper Co Raritan Copper Works Baltanore Copper Sing and Rolling Co American Sinelting and Refund Co United States Metals Refund Co United States Metals Refund Co Anaconda Cop M n Co (old plant) Anaconda Cop M n Co (old plant) Anaconda Cop M n Co (old plant) Taconsa Snielting Co Calumet & Heela M ung Co Couvolidated Mining and Smerting Co	Laurel Hu. N. Y. Perth Amboy, N. J. Canton, Md. Perth Amboy, N. J. C. rone, N. J. Newark, N. J. Great Falls. Mont Great Falls. Mont Facoma, Wash Culumet, Mich. Trad, B. C. Frad.	400,000,000 400,000,000 348,000,000 209,000,000 48,000,000 65,000 000 38 000,000	400,000,000 400,000,000 336,000,000 210,000,000 48,000,000 65,000,000 85,000,000 1,778,000,000	400,000,000 400,000 400,000 400,000 450,000,000 500,000,000 348,000,000 400,000 600,000 600,000 600,000 240,000 000 240,000 000 240,000 000 240,000 000 240,000 000 240,000 000 240,000 000 250,000,000 12,20,000,000 12,496,400,000 27,78,000,000 1,778,000,000 2,496,400,000 2,794,000,000 2,794,000,000	450,000,000 460,000 000 660,000 000 250,000,000 48,000,000 65,000 000 130,000,000 8,470,000 8,470,000	500,000,000 460,000,000 720,000,000 250,000,000 48,000,000 65,000,000 180,000,000 65,800,000 65,800,000 14,000,000

New * Official figures furnished by the respective companies. † Buffalo works of Calumet & Heels dismantled in fall of 1914. works put into operation in 1914. † New works put in operation in 1914.

SECTION III

PHYSICAL CONSTANTS

The Fundamental Laws of Physics

= mass \times acceleration; f = ma**Force**

Momentum = mass \times velocity; M = mvEnergy = $\frac{1}{2}$ mass \times velocity²; $E = \frac{1}{2}$ mv^2

= force \times distance = fs = masWork

Harmonic motion, period = $2\pi \sqrt{\frac{\text{length}}{\text{acceleration}}}$, or in a pendulum

 $T = 2\pi \sqrt{\frac{l}{a}}$

Laws of a falling body: v = velocity at end of t seconds, S =space traversed in t seconds, $S_t = \text{space traversed from } t$ to (t+1) seconds

v = gt $S = \frac{1}{2}gt^{2}$ $S_{t} = \frac{1}{2}g(2t + 1)$

"Centrifugal force" = $mr\omega^2$, where ω = angular velocity. Torsional pendulum: $T = 2\pi \sqrt{\frac{2lI}{\pi nr^6}}$

where T = period, l = length, I = moment of inertia of masson end, n = coefficient of rigidity, r = radius of wire. Young's modulus, coefficient of elasticity:

 $F_1 = \frac{p}{\underline{\Delta l}} = \frac{fl}{\pi r^2 \Delta l};$

l = length, $\Delta l = change in length$.

Pressure in liquids = ρgh , where ρ = density and h = height of column.

Speed of escape of a liquid from an orifice, if there were no viscosity,

 $S = \sqrt{\frac{2p}{q}}$

Boyle's law, behavior of perfect gases under varying volumes, pressures and temperatures:

pv = RmT, where R is the so-called gas constant and T is

absolute temperature.

Under changes so sudden that the heat generated by compression (or absorbed by expansion) cannot radiate or be absorbed from external objects:

 $pv^{\gamma} = Rmt(\gamma = 1.406 \text{ approx.})$

Electricity: Ampere, the unit of current strength, I; volt, the unit of electromotive force, E; ohm, the unit of resistance, R; coulomb, the unit of quantity, Q; watt, the unit of power, P; joule, the unit of work, J; farad, the unit of capacity, C; henry, the unit of inductance, l. t = seconds. $I = \frac{E}{D}$ (Ohm's law); Q = It, $C = \frac{Q}{E}$, W = QE, P = IE, $P = \frac{E^2}{R} = I^2R = \frac{C}{R}$ $\frac{W}{A} = \frac{QE}{A}$.

Heating effect of a current = $i^2Rt = \frac{E^2t}{R}$.

Composition of the Air¹

	By weight	By volume	Expired air by volume
Oxygen Nitrogen Argon ² CO ₂	23.024 75.539 1.337 0.040	20.941 78.122 0.937	15.4 79.2 4.33

PYSCHROMETRIC TABLES³

Measurement of Atmospheric Moisture.—The quantity of moisture mixed with the air under different conditions of temperature and degree of saturation may be measured in several distinctly different ways. Many of these, however, are not practicable methods for daily observations, or are not sufficiently accurate. Probably the most convenient of all methods and the one most generally employed is to observe the temperature of evaporation—that is, the difference between the temperatures indicated by wet- and dry-bulb thermometers. The most reliable instrument for this purpose is the sling, or whirled psychrometer. In special cases, rotary fans or other means may be employed to move the air rapidly over the thermometer bulbs. In any case satisfactory results cannot be obtained from observations in relatively stagnant air. A strong ventilation is absolutely necessary to accuracy.

Sling Psychrometer.—This instrument consists of a pair of

thermometers, provided with a handle, which permits the thermometers to be whirled rapidly, the bulbs being thereby strongly affected by the temperature of and moisture in the air. bulb of the lower of the two thermometers is covered with thin

muslin, which is wet at the time an observation is made.

The Wet Bulb.—It is important that the muslin covering for According to Ramsay (cf. Benson's "Industrial Chemistry," p. 38. The Macmillan Co.)

Including the other inert gases. The rare gases are present in air in the following proportions by weight: krypton, 0.028 per cent.; xenon, 0.005; neon, 0.00038; helium, 0.000056 per cent.

* C. F. Marvin's Tables, Weather Bureau Bulletin No. 235.

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT Pressure = 30,0 inches of mercury

H 50.0	Depression of wet-bulb thermometer $(t-t')$
temp, (Vapor press, In., Hg.	0.2 0.4, 0.6 0 8 1 0 1 2 1.4 1 6 1 8 2 0 2 2 2.4, 2.6 2.8, 3 0
-400.0039 -39 41 -38 44 -37 46 -36 48 -350.0051 -34 59	-52 -50 -49 -48 -46 -45 -43 -59 -60 0.0010 -50 0.0021 -60 -60 0.0010 -50 0.0021 -60
-33 57 -32 61 -31 65 -300.0069 -29 74 -28 78 -27 83 -26 89 -250 0094 -240.0100 -23 106 -22 112 -21 119 -200.0126 -19 133 -18 141 -17 150 -16 159 -150.0168 -11 178 -13 168 -12 199 -11 210 -160 6222 - 9 234	-40
- 8 247 - 7 260 - 6 275 - 50.0291 - 4 307 - 3 325 - 2 344 - 1 363 - 0 0 0383 + 1 403 - 423 - 444 - 4 67 - 50.0491 - 6 60 - 10 0.0631 - 11 668 - 12 696 - 13 735 - 14 772 - 15 0.0310 - 18 933 - 19 0.0975 - 30 0.1026	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT.

Continued

Pressure = 30.0 inches of mercury

Air			D	ерге	ssion	of	wet-l	bulb	ther	mom	eter	· (t -	- t')		
temp., t	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0
2 3 4	-56 -43 -34														
5 6 7 8 9	29 25 21 18 15	-30 -26 -22	—39 —31 —26	-53 -41 -32	58	1									
10 11 12 13 14	-13 -10 - 8 - 6 - 4	13	—16 —13 —10	19 15 12	22 19	—27 —22 —18	—34 —27 —22	-46 -34 -27	-34	46 33	45				
15 16 17 18 19	- 2 ± 0 + 2 + 3 + 5	+ 2	- 5 - 3 - 1 + 1 + 3	- 7 - 5 - 3 - 1 + 1	- 9 - 7 - 4 - 2 ± 0	— 9 — 6 — 4	$-11 \\ -8 \\ -6$	-18 -14 -11 - 8 - 5	—17 —13 —10		16	-31 -24 -19	—42 —30	-39 29	57 37 27
20	+ 7	+ 6	+ 4	+ 3	+ 2	± 0	_ 1	— 3	<u> </u>	_ 7	<u> </u>	_11	-14	-17	<u>-21</u>

the wet bulb be kept in good condition. The evaporation of the water from the muslin always leaves in its meshes a small quantity of solid material, which sooner or later somewhat stiffens the muslin so that it does not readily take up water. will be the case if the muslin does not readily become wet after being dipped in water. On this account it is desirable to use as pure water as possible, and also to renew the muslin from time to time. New muslin should always be washed to remove sizing, etc., before being used. A small rectangular piece wide enough to go about one and one-third times around the bulb. and long enough to cover the bulb and that part of the stem below the metal back, is cut out, thoroughly wetted in clean water, and neatly fitted around the thermometer. It is tied first around the bulb at the top, using a moderately strong thread. A loop of thread to form a knot is next placed around the bottom of the bulb, just where it begins to round off. As this knot is drawn tighter and tighter the thread slips off the rounded end of the bulb and neatly stretches the muslin covering with it, at the same time securing the latter at the bottom.

To Make an Observation.—The so-called wet bulb is thoroughly saturated with water by dipping it into a small cup. The thermometers are then whirled rapidly for 15 or 20 seconds; stopped and quickly read, the wet bulb first. This reading is kept in mind, the psychrometer immediately whirled again and a second reading taken. This is repeated three or four times, or more, if necessary, until at least two succeeding readings of the

Continued on page 98.

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Continued Pressure = 30.0 inches of mercury

13	H.S.				I		essio		wet-	bulb	ther		nete	r (t -	- t')	
Air temp.	press in. H	1	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
20 0 21 0	.103 .108	18 19	16 18	14 16	12 14	10 12	8 9	5 7	3 5	- 2 ± 0 + 2	- 7 - 4	—13 — 9	16	-37 -27	60	
23 0.	.113	20 21	19 20	17	15 16	13	11 12	10	7	4	一 2 ± 0 + 2	— 6 — 4	-12 - 9	-20 -16	-26	-57
25 0.	.124	23 24 25	21 22 23	19 20 22	17	15	13	11 13	10 12	6 8	+ 2 5 7	-1 + 1	$-6 \\ -3 \\ -1$	—12 — 8	-15	-25
27 0.	.136 .143 .150	26 26 27	24 24 25	22 23 24	20 21 22	18 19 21	16 18 19	14 16 17	13	9 11 13	8	3 5 7	+ 2	- 5 - 2	-11 - 7	—18 —14
29 0.	. 157 . 164	28 29	26 27	25 26	23 25	22 23	20 21	18 20	16 18	14 16	10 12 14	9 11	68	± 0 + 3 5	- 1 + 2	— 9 — 5
31 0.	.172 .180	30 31	28 30	27 28	26 27	24 25	23 24	21 22	19 21	17 19	15 17	13 15	10 12	8 10	4	一 2 ± 0 + 3
33 0.	. 187 . 195	32 33	31 32	29 30	28 29	27 28	25 26	24 25	22 23	20 22	18 20	16 18	14 16	12 13	9	6 8 10
35 0.	.203 .211	34 35	33 34	31 32	30	29 30	28 29	26 27	25 26	23 24	21 23	19 21	17 19	15 17	13 15	10 12
37 0. 38 0.	.219 .228	36 37	35 36	33 34	32 33	31 32	30 31	28 29	27 28	26 27	24 25	22 24	21 22	19 20	17 18	14 16
40 0.	.237 .247	38 39	37 38	35 37	34 35	33 34	32 33	31 32	29 30	28 29	27 28	25 26	23 25	22 23	20 21	18 20
42 0.	. 256 . 266	40 41	39 40	38 39	36 38	35 36	34 35	33 34	31 33	30 31	29 30	27 29	26 27	24 26	23 24	21 23
44 0.	277	42 43	41 42	40	39 40	37 38	36 37	35 36	34 35	32 34	31 32	30 31	28 30	27 28	25 27	24 25
46 0.	.298 .310 .322	44 45 46	43 44 45	42 43 44	41 42 43	40 41 42	38 40 41	37 38 40	36 37 38	35 36 37	34 35 36	32 33 35	31 32 33	30 31 32	28 29 31	27 28 29
48 0.	334 347	47 48	46 47	45 46	44 45	43 44	42 43	41 42	40 41	38 40	37 38	36 37	35 36	33 34	32 33	31 82
50 0.	360 373	49 50	48 49	47 48	46	45 46	44 45	43 44	42 43	41	40 41	38 40	37 38	36 37	34 36	33 84
52 0.	387 402	51 52	50 51	49 50	48 49	47 48	46 47	45 46	44 45	43 44	42 43	41 42	40 41	38 40	37 38	86 87
54 0. 55 0.	.417 .432	53 54	52 53	51 52	50 51	49 50	48 50	47 49	46 48	45 47	44 45	43 44	42 43	41 42	40 41	38 4 0
57 0.	448 465	55 56	54 55	53 54	53 54	52 53	51 52	50 51	49 50	48 49	47 48	46 47	44 46	43 45	42 43	41 42
59 0.	482 499	57 58	56 57	55 56	55 56	54 55	53 54	52 53	51 52	50 51	49 50	48 49	47 48	46 47	45 46 47	44
60 0. 61 0. 62 0.	517 536 555	59 60 61	58 59 60	57 59 60	57 58 59	56 57 58	55 56 57	54 55 56	53 54 55	52 53 54	51 52 53	50 51 53	49 50 52	48 49 51	48 50	46 47 48
63 0. 64 0.	575 595	62 63	61 62	61 62	60 61	5 9 60	58 59	57 58	56 57	55 57	55 56	54 55	53 54	52 53	51 52	50 51
65 IO.	.616 f	64 65	63 64	63 64	62 63	61 62	60 61	59 60	59 60	58 59	57 58	56 57	55 56	54 55	53 54	52 53
67 0. 68 0.	638 661 684	66 67	65 67	65 66	64 65	63 64	62 63	62 63	61 62	60 61	59 60	58 59	57 58	56 57	55 57	54 56
69 0.	707 732	68 69	68 69	67 68	66 67	65 66	64 65	64 65	63 64	62 63	61 62	60 61	59 61	59	58 59	57 58
71 0. 72 0.	757 783	70 71	70 71	69 70	68 69	67 68	67 68	66 67	65 66	64 65	63 64	62 64	62 63	61 62	60	59
73 0. 74 0.	684 707 732 757 783 810 838 866 896	72 73	72 73	71 72	70 71	69 70	69 70	68 69	67 68 69	66	66 67	65 66	64 65 66	63 64 65	62 63 64	61 62 64
75 0. 76 0. 77 0.	896 924	74 75 76	74 75 76	73 74 75	72 73 74	71 72 73	71 72 73	70 71 72 -	70 71	68 69 71	68 69 70	67 68 69	67 68	66 67	66 67	65 66
78 0. 79 0.	926 957 989 022	77 78	77 78	76 76 77	75 76	75 76	74 75	73 74	72 73	72 73	71 72	70 71	69 70	69 70	68 69	67 68
80 1.	022	79	79	78	77	77	76	75	74	74	73	72	72	71	70	69

METALLURGISTS AND CHEMISTS' HANDBOOK 80

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Continued

Pressure = 30.0 inches of mercury

	-			De	pres	sion :	of w	et-b	ույլ ույլ	ьего	00111	eter	(2 -	(')		
Air temp,	press,	80	8 5	9.0	9 5	10 0	10 5	11 0	11 5	12 0	12 5	13 n	13 5	14 0	14.5	15.0
$\begin{array}{c} \textbf{26} \\ 2789000000000000000000000000000000000000$	130 136 143 150 156 143 150 156 156 156 156 156 156 156 156 156 156	31 23 7 4 1 2 8 7 10 12 14 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 22 4 16 18 12 12 12 12 12 12 12 12 12 12 12 12 12	+ 1062 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	395 5 6 8 1 3 5 7 9 0 3 6 8 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	-57 31 19 51 10 10 11 10 11 10 11 11 11 11 11 11 11	+ 1 ·	32014	-41 -25 -10 -10 -10 -10 -10 -10 -10 -10 -10 -10	569 12 6 2 2 5 8 9 1 1 2 1 2 1 2 2 2 4 6 7 1 1 2 1 2 2 2 4 6 7 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	- 36 - 22 - 36 - 21 - 3 - 3 - 11 - 14 - 16 - 16 - 16 - 16 - 16 - 16 - 16 - 16	104047024630245790235558912446655556780F	30 181 1 5 1 3 0 9 11 13 16 8 20 2 2 1 1 13 16 8 20 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		-45 24; -14 -73 -15 10 13 15 10 12 22 24 25 27 29 32 43 44 46 47 47 47 47 47 47 47 47 47 47 47 47 47		-307-1050-17-10-15-17-19-15-17-19-15-17-19-15-17-19-15-17-19-15-17-19-17-17-17-17-17-17-17-17-17-17-17-17-17-

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Continued

Pressure = 30.0 inches of mercury

Aie	Depression of wet-bulb thermometer $(t-t')$
temp., t	15.5 16 0 18.5 17 0 17 5 18 0 18.5 19 0 19 5 20 0 20.5 21 0 21 5 22 0 22.
47 48 49 50 51 52 53 54 55 56 57 58 60 61 62 63 64 65 67 77 77 78 77 78 79 80	-20 -41
£	Depression of wet-bulb thermometer (t - t') 23 0 23.5 24 0 24 5 25 0 25.5 26 0 26.5 27 0 27 5 28 0 28 5 29 0 29.5 30.
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79	-54 -22 -3 -11 -23 + 2 - 3 -11 -24 7 + 2 - 3 -11 -24 11

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Continued

Pressure = 30.0 inches of mercury

				essui					i me				4/\		
			De	prese	sion	oi w	et-bi	ub t	herm	ome	ter (t —	t')		
Air temp., Vapor press.,	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
80 1.022	79	77	76	74	73	72	70	68	67	65	63	62	60	58	56
81 1.056 82 1.091	80 81	78 79	77 78	75 77	74 75	73 74	71 72	70 71	68 69	66	65 66	63 64	61 62	59 60	57 59
83 1.127	82	80	79	78	76	75	73	72	70	69	67	65	64	62	60
84 1.163	83	81	80	79	77	76	74	73	71	70	68	66	65	63	61
85 1.201 86 1.241	84 85	82 83	81 82	80 81	78 79	77 78	75 76	74 75	72 73	71 72	69 70	68	66	64	62 64
87 1.281	86	84	83	82	80	79	78	76	75	73	72	70	68	67	65
88 1.322	87	85	84	83	81	-80	79	77	76	74	73	71	69	68	66
89 1.364	88	86	85	84	82	81	80	78	77	75	74	72	71	69	67
90 1.408 91 1.453	89 90	87 88	86 87	85 86	83 85	82 83	81 82	79 80	78 79	76 78	75 76	73 75	72 73	70 71	69 70
92 1.499	91	89	88	87	86	84	83	81	80	79	77	76	74	73	71
93 1.546	92	90	89	88	87	85	84	83	81	80	78	77	75	74	72
94 1.595 95 1.645	93 94	92 93	90 91	89 90	88	86 87	85 86	84 85	82 83	81 82	79 80	78 79	76 78	75 76	73 74
96 1.696	95	94	92	91	90	88	87	86	84	83	82	80	79	77	76
97 1.749	96	95	93	92	91	89	88	87	85	84	83	81	80	78	77
98 1.803 99 1.859	97	96	94	93	92	90	89	88 89	87 88	85	84	82	81	79	78
99 1.859 100 1.916	98 99	97 98	95 96	94 95	94	92 93	90 91	90	89	86 87	85 86	83 85	82 83	81 82	79 80
101 1.975	100	99	97	96	95	94	92	91	90	88	87	86	84	83	81
102 2.035	101	100	98	97	96	95	93	92	91	89	88	87	85	84	83
103 2.097 104 2.160	102 103	101 102	99 100	98 99	97 98	96 97	94 95	93 94	92 93	91 92	89	88 89	86	85 86	84 85
105 2.225	104	103	101	100	99	98	96	95	94	93	91	90	89	87	86
106 2.292	105	104	102	101	100	99	98	96	95	94	92	91	90	88	87
107 2.300	106	105	103	102	101 102	100	99 100	97 98	96	95	93	92	91	90	88
108 2.431 109 2.503	107 108	106 107	104 105	103 104	103	101 102	101	99	98	96 97	95 96	93 94	92 93	91 92	89 90
110 2.576	109	108	106	105	104	103	102	100	99	98	97	95	94	93	91
111 2.652	110		108		105	104	103	102	100	99	98	96	95	94	93
	111 112	110 111	109 110		106 107	106	104 105	108 104	101 102	100 101	99 100	98 99	96 97	95	94 95
114 2.891	113	112	111	109		107	106	105			101	100	98	97	96
115 2.975	114	113	112	110		108	107	106	104		102	101	99	98	97
116 3.061 117 3.148	115 116	114 115	113 114			109 110	108 109	107 108	105 107		103 104	102 103	101 102	99	98
118 3.239	117		115			iii	110	109	108		105	104	103	101	100
119 3.331	118	117	116	114	113	112	111	110	109	107	106	105	104	102	101
120 3.425	119	118	117 118		114 115	113	112			108	107	106	105	104	102
121 3.522 122 3.621	120 121	119 120	119		116	114 115	113 114		111 112	109 110	108 109	107 108	106 107	10 5 10 6	103 104
123 3.723	122	121	120	119	117	116	115	114	113	110 112	110	109	108	107	106
124 3.827	123	122	121		118	117	116		1114	1113	111	110	109	108	107
125 3.933 126 4.042	12 4 12 5	123 124	122 123	121 122	119 120	118 119	117 118		115 116	114 115	113	111 112	110 111	109 110	108 109
127 4.154	126	125	124	123	121	120	119	118	117	116	114	113	112	111	110
128 4.268	127	126	125	124	122	121	120	119	118	117	116	114	113	112	111
129 4.385 130 4.504	128 129	127 128	126 127	125 126		122 123	121 122	120 121		118 119	117 118	115 116	114 115	113 114	112 113
131 4.627	130	129	128	127		123 124	123	122	121	120	119	117	116	115	114
132 4.752	131	130	129	128	126	125	124	123	122	121	120	119	117	116	115
133 4.880	132	131	130	129		126	125	124	123		121	120	118	117	116
134 5.011 135 5.145	13 3 13 4	132 133	131 132	130 131		127 128	126 127	125 126	12 4 12 5		12 2 123	121 122	119 120	118 119	117 118
136 5.282	135	134	133	132	131	129	128	127	126	125	124	123	122	120	119
137 5.422	136	135	134	133	132	130	129	128	127	126	125	124	123	121	120
	137 138	136 137	135 136	134 135	133 134	13 1 13 2	130 131	129 130	128 129		126 127	125 126	124 125	122 123	121 122
	139	138	137	136		133	132	131	130		128	127	126	124	123
							<u> </u>								

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Continued Pressure = 30.0 inches of mercury

-				PN	essur	e =	30.0	ine	168 0	f me	rcury					·
2 ¢	30r			De	pres	sion	of w	ret-b	ulb t	therr	nom	eter	(t -	<i>t'</i>)		
Air temp.,	Vapor press., e	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	1.022	54 55	52 53	50 51	47	44 46	42 43	39 41	36	32 34	28 31	24 27	20 22	13 17	6 10	-7 +7.
82	1.091	57	55	52	50	48	45	42	39	36	33	29	25	20	14	+7
83	1.127	58	56	54	52	49	47	44	41	38	35	31	27	23	18	11
84 85	1.163	59 61	57 59	55 57	53 54	51 52	48 50	46 48	43	40	37 39	34 36	30 32	26 28	21 24	15 19
86	1.241	62	60	58	56	54	52	49	47	44	41	38	34	31	27	22
87 88	1.281	63	61	59	57	55	53	51	48	46	43	40	36	33	29	25
89	1.322 1.364	64 66	62 64	61 62	59 60	57 58	55 56	52 54	50 51	47	45 46	42- 44	38 41	35 37	31 34	27 30
90	1.408	67	65	63	61	59	57	55	53	51	48	45	43	39	36	32
91 92	1.453 1.499	68 69	66	65 66	63 64	61 62	59 60	57 58	55 56	52 54	50 51	47 49	44	41 43	38 40	35 37
93	1.546	71	69	67	65	63	62	60	58	55	53	51	48	45	42	39
94 95	1.595	72	70 71	68	67	65	63	61 62	59 60	57.	55	52	50	47	44	41
96	1.696	73 74	72	71	68 69	67	66	64	62	58 60	56 58	54 55	52 53	49 51	48	43
97	1.749	75	74	72	70	69	67	65	63	61	59	57	55	52	50	47
98 99 .	1.803	76 78	75 76	73 74	72 73	70 71	68 69	66	64 66	63 64	61 62	58 60	56 58	54 56	52 53	49 51
100	1.916	79	77	76	74	72	71	69	67	65	63	61	59	57	55	52
101 102	1.975 2.035	80 81	78 80	77 78	75 76	74 75	72 73	70 72	69 70	67 68	65 66	63	61	59 60	56 58	54 56
103	2.097	82	81	79	78	76	74	73	71	69	68	64 66	62 64	62	60	57
104	2.160	83	82	80	79	77	76	74	72	71	69	67	65	63	61	59
106	2.225 2.292	84 86	83 84	82 83	80 81	78 80	77 78	75 77	74 75	72 73	70 72	68 70	67 68	65 66	63	61 62
107	2.360	87	85	84	82	81	79	78	76	75	73	71	69	67	66	64
	2.431 2.503	88 89	86	85	84 85	82 83	81 82	79 80	77	76 77	74 75	72 74	71 72	69 70	67	65 66
110	2.576	90	89	87	86	84	83	81	80	78	77	75	73	72	70	68
111	2.652	91	90	88	87	86	84	83	81	80	78	76	75	73	71	69
112 113	2.730 2.810	92 93	91 92	90 91	88	87 88	85 86	84 85	82 84	81 82	79 80	78 79	76	74 76	72 74	71 72
114	2.891	94	93	92	90	89	88	86	85	83	82	80	79	77	75	73
115 116	2.975 3.061	96 97	94	93	92	90 91	89 90	87 88	86	84 86	83 84	81 83	80 81	78 79	76 78	75 76
117	3.148	98	96	95	94	92	91	90	88	87	85	84	82	81	79	77
118	3.239	99	98	96	95	94	92	91	89	88	86	85	84	82	80	79
120		100 101	99 100	97	96 97	95 96	93 94	92 93	91 92	89	88 89	86 87	85 86	83 84	82 83	80 81
121	3.522	102	101	100	98	97	96	94	93	91	90	89	87	86	84	83
122		103 104	102 103	101 102	99 100	98 99	97 98	95 96	94 95	93	91 92	90 91	88 90	87 88	85 87	84 85
124	3.827	105	104	103	102	100	99	98	96	95	94	92	91	89	88	86
125		10 6 10 7	105 106	104 105	103 104		100 101	99 100	97 99	96	95	93 94	92 93	90 92	89 90	88
127		109	107	106	105		102	101	100	98	97	96	94	93	91	90
128	4.268	110	108	107	106		103	102	101	99	98	97	95	94	93	91
120		111 112	109 110	108 109	107 108		104 106	103 104	102 103	101 102	99 100	98 99	97 98	95 96	94 95	92
131	4.627	113	112	110	109	108	107	105	104	103	101	100	99	97	96	95
		114 115	113 114	111 112	110 111		108 109	106 108	105 106	104 105		101 102	100 101	99 100	97 98	96
124	5.011	116	115	114	112	111	110	109	107	106	105	104	102	101	100	98
135	5 .145	117.	116	115	113	112	111	110	108	107	106	105	103	102	101	99
136 137	p.282 5.422	118 119	117 118	116 117	114 116	113 114	112 113		110 111	108 109		106 107	104 106	103 104	102 103	101 102
138	5.565	120	119	118	117	115	114	113	112	110	109	108	107	105	104	103
		121 122	120 121	119 120	118 119	116 117	115 116	114 115	113 114	112 113		109 110	108 109	107 108	105 106	104 105
270	5.862		121	120	118	14.4	1	1-10	144	1210		1.10	100	1.00	1-00	

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Continued Pressure = 30.0 inches of mercury

				Pr	2 88U 1	:e =	30.0) inc	hes o	f me	rcur	<u>y</u>				
2:.	9.			De	pres	sion	of w	et-b	ulb t	hern	ome	ter	(t -	ť)		
Air temp.	Vapor press., e	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
7 3		<u> </u>	02	00	01	00	100	! "	00	00	1 20			1 20		
80 .81 82 83	1.022 1.056	- 53 - 18					1	Ì	:							
82	1.091	- 6	- 43										ļ			
83	1.127	+ 2	—15	99				1								
84 85 86	1.163 1.201	8 12	一 4 十 3	$-33 \\ -12$					•				İ			
86	1.241	16	9	- 2	-27				•				İ			
87 88	1.281 1.322	20 23	13 17.	+ 5	−10 ± 0	-22								Ì		
87 88 89	1.364	26	21	10 15	+ 6	- 7			ļ							
90 91	1.408 1.453	28	24 27	19 22	11 16	+ 1 8	-17	-4 0						}		
92	1.499	31 33	29	25	20	13	+ 4	-13								
93	1.546	36	32	28	23	17	10	- 2	-28							
94 95	1.595 1.645	38 40	34 37	30 33	26 29	21 24	14 19		-9 + 1	- 2 0						
96	1.696 1.749	42	39	35	31	24 27	22	16	8	- 5			1	1		
97	1.749	44	41 43	38	34 36	30	25 28	20 23	13 17	$+3 \\ 10$	$-15 \\ -2$					
99	1.803 1.859	46 48	45	40 42	39	35	31	26 26	21	15	+ 6	10	1			
100	1.916	50	47	44	41	37	33	29	25	19	12	+ 1	-22			
101 102	2 035	52 53	49 51	46 48	43 45	40 42	36 38	32 35	28 31	23 26	21	8 14	-5 + 4	14		
103	2.097	55	53	50	47	44	41	37	33	29	24	18	11	- 2	-32	
104	2.160	57	54 56	52	49 51	46 4 8	43 45	40 42	36 38	32 34	27	22 26	16 20	+ 7 13	-9 + 2	-2 0
106	2.292	58 60		54 55	53	50		44	41	37	33	29	24	18	7 5	- 4
98 99 100 101 102 103 104 105 106 107 108 109 110	2.360	62	59	57	55	52	49	46	43	40	36	32	27	22	15	+ 5
108	2.431	63 64	61 62	59 60	56 58	54 56	51 53	48 50	45 47			35 37	30 33	25 29	20 23	12 17
110	2.576	66	64	62	60	57	55	52	50	47	43	40	36	32	27	21
111	2.652	67 69	65 67	63 65	61 63	59 61	57 58	54 56	52 54	49 51	46 48	42 45	39 41	35 37	30 33	25 29
113	2.810	70	68	66	64	62	60		55	53	50	47	44	40	36	32
114	2.891	72	70	68	66	64	62	59	57	55	52	49	46	43	39	35 38
110	12.975 13.061	73 74	71 73	69 71	67 69	65 67	63 65	61 63	59 60	56 58		51 53	48 50	45 47	42 44	40
117	3.148	76	74	72	70	68	66	64	62	60	58	55	52	49	46	43
118	3.239 2.231	77 78	75 77	74 75	72 73	70 71	68 69	66 67	64 65	62 63	59 61	57 59	54 56	51 53	49 51	45 48
120	3.425	80	78	76	75	73	71	69	67	65	63	60	58	55	53	50
121	3.522	81	79	78	76	74	72	70	68 70	66			60 62		55 57	52
122	3.723	82 84	81 82	79 80	77 79	76 77	74 75	72 73	71	68 69	67		63		58	40 43 45 48 50 52 54 56 58
124	3.827	85	83	82	80	78	77	75	73	71	69	67	65	63	60	58
125 126	3.933	86 87	84 86	83 84	81 83	80 81	78 79	76 78	74 76	72 74	71 72	69 70	66 68	64 66	62 64	60 62 63 65 67
127	4.154	88	87	85	84	82	81	79	77	75	74	72	70	68	65	63
128	4.268	90	88	87	85 86	84 85	82 83	80 82	79 80	77 78	75 76	73 75	71 73	69 71	67 69	65
130	4.504	91 92	89 91	88 89	88	86	85	83	81	80	78	76	74	72	70	68
131	1.916 1.975 2.035 2.097 2.160 2.225 2.360 2.576 2.576 2.576 2.810 2.810 2.891 2.975 3.148 3.239 3.425 3.522 3.621 3.723 3.827 3.933 4.042 4.154 4.268 4.385 4.504 4.752	93	92	90	89	87	86	84	83	81	79	77	76	74	72	70
112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 130 131 132 133 134 135 136 137	4.752	94 96	93 94	92 93	90 91	89 90	87 88	86 87	84 85	82 84	81 82	79 80	77 78	75 77	73 75	68 70 71 73
134	4.880 5.011 5.145 5.282 5.422 5.565 5.712 5.862	97	95	94	93	91	90	88	87	85	83	82	80	78	76	74
135	5.145	98	97	95	94	92	91	89	88	86	85	83	81	80	78 70	74 76 77
130	0 . 282 5 . 422	99 100	98 99	96 98	95 96	94 95	92 93	91 92	89 90	88 89	86 87	84 86	83 84	81 82	79 81	77
138	5.565	101	100	99	97	96	95	93	92	90	89	87	85	84	82	80
139	5.712 5 2A9	103 104	101 102	100 101	99 100	97 98	96 97	94 96	93 94	91 93	90 91	88 90	87 88	85 86	83 85	82 83
TAL	h. one	I	102	101	400	0	l "	1 00	- 07	90	7	1		30	30	

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Continued
Pressure = 30.0 inches of mercury

*			De	pres	sion	of w	ret-b	ulb t	hern	nom	eter	(t —	<i>t'</i>)		
Air temp.,	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
106 107 108 109	-56 -12 ± 0 + 8									•					
110 111 112 113 114	14 19 23 27 30	11 17 21	- 16 - 1 + 8 14 19	-35 - 8 + 3		– 5 0									
115 116 117 118 119	33 36 39 42 44	29 32 35 38 41	23 27 30 34 37	16 21 25 29 32	+ 7 14 19 23 27	$+\overline{2}$	$ \begin{array}{r} -22 \\ -3 \\ +7 \end{array} $	∸11 + 2	— 25						
120 121 122 123 124	47 49 51 53 55	43 46 48 50 52	89 42 45 47 49	35 38 41 44 46	30 34 37 40 43	29 32 36	19 23 27 31 34	10 16 21 25 29	- 4 + 6 14 19 24	-12 + 1 10 17	27 4	— 13			
125 126 127 128 129	57 59 61 63 64	54 56 58 60 62	52 54 56 58 60	49 51 53 55 57	45 48 50 52 54	42 44 47 49 51	37 40 43 46 48	33 36 39 42 45	28 31 35 38 41	22 26 30 33 37	28	+ 2 11 17 22 26	-29 - 4 + 7 14 20	$-13 + 2 \\ 11$	-27 -4
130 131 132 133 134	66 68 69 71 73	64 66 67 69 71	62 63 65 67 68	59 61 63 64 66	56 58 60 62 64	54 56 58 60 62	5 1 53 55 57 59	47 50 52 54 56	44 46 49 51 53	40 43 45 48 50	39 42 44	30 34 37 40 43	25 29 32 36 39	17 23 27 31 34	+ 7 15 21 25 29
135 136 137 138 139	74 76 77 78 80	72 74 75 77 78	70 72 73 75 76	68 70 71 73 74	66 67 69 71 72	63 65 67 69 70	61 63 65 66 68	58 60 62 64 66	56 58 60 62 64	53 55 57 59 61	50 52 54 56 58	46 49 51 53 56	42 45 48 50 53	38 41 44 47 50	33 37 40 43 46
140	81	80	78	76	74	72	70	6 8	65	63	60	58	5 5	52	49

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Continued Pressure = 23.0 inches of mercury

-	- 60	1							cnes	-						
p.	Vapor bress.,			De	press	sion	of w	et-b	ulb t	hern	ome	eter	(t-	<i>t'</i>)		
Air temp.	Vapo press.,	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
40 30	0.0039	-49 -48					-		е	į	e	_		t -		
38	44	-46	-59	ļ	}		-		.0010	 52	0.00		1 (U.) 80	2 0.3	10.4	$\frac{[0.5]}{1}$
—37 —38	46	-45 -43						-59	11	51]]	l 9	59		-	1
35	0.0051	4 2	52	[]	•	'		-58 -57	12 13		0.002		58 56			1
—34 —33	54 57	-40 39		ļ			-	-56	13	-4 8	2	24	54			
-32	0.0039 41 44 46 48 0.0051 54 57 61	38	-46	59			_	-54	.0015 16	46			53 51 — 5	9		
30	KU. UUDU	<u></u>	42	—55 —52	•		<u> -</u>	-53	.0017	-45 -44				7	ł	
29 28 27	74 78		40 38	- 49 - 46						43	3	33	17-5	3		
-27	83	3 0	-36	-4 4	—55					$-42 \\ -41$				1 -60 0 -58		
26 25	89 0.0094		—34 —32	-41 -39	-51 -48				1		0.003	39	4-4	9-56	3	
24 23	0.0100	-27	31	36 34	-45 -42	57 51				—38	. 4	4 -4	2-4	6 -52	≥ 59	
22	1 112	25	29	33	39	-4 7				-37 -36			1 4	5-50 3-49		
21 20	119 0.0126	24 23	-27 -26	-31 -29	-36 -34	$-44 \\ -40$	—57 —51			-35	0.005	51 —3	89 4	2 -47	/52	Ì
19 18	133	$-22 \\ -20$	24	28	32	—37	-4 7	1	,	34 33		7 3	7—4 6—3	9-43		
17	1 150	—19	22	26 25	28	—35 —32	— 4 3 —39	48	3	$-32 \\ -31$		$\begin{bmatrix} 1 & 3 \\ 5 & 3 \end{bmatrix}$	5 —3 3 —3	$ \begin{array}{c c} 8 & -42 \\ 6 & -40 \end{array} $		52 49
16 15	159 0.01 6 8	—18 —17	-20 -19	23 22	26 25	30 28	35 33	—43 —39			0.006		2 - 3			-47
-14 -13	178 188	16	—18	20	23	26	30	36	-4 4	-57 -49						
12	199	14	-17 - 16	—19 —18	—22 —20	25 23	—28 —26	30	 35	-4 3	— 56					
-11 -10	$\begin{smallmatrix}210\\0.0222\end{smallmatrix}$	—13 —12	—14 —13	—16 —15	—19 —17	21 20	24 22			39 34	$-48 \\ -42$	<u>55</u>			-	
 9 8	234	11	—12 —11	—14 —13	—16 —15	18 17	$-21 \\ -19$	 24	—27	—31	—37 —33	46	ł			
— 7	260	— 8	-10	12	14	-15	—17	-20	23	26	30	-35	-44	56	ļ	
$-6 \\ -5$	$\begin{smallmatrix}275\\0.0291\end{smallmatrix}$	— 7 — 6	- 9	—10 — 9	12 11	—14 —12	16 14	-18 -16	-21 19	24 22	—27 —25	$-32 \\ -29$	—38 —33	-47 -40	51	
$-4 \\ -3$	307	- 5	— 6 — 5	$-8 \\ -7$	10	—11 —10	—13 —11	—15 —13	-17	19 17	22 20	26 23	30 26	35 31	-43 -37	57 46
-2	344	-3	4	— 6	$-\frac{8}{7}$	— 8	—10	12	-14	—16	18	20	23	27	32	38
- 1 0	363 0.0383	2 1	$-3 \\ -2$	4 3	- 6 - 4	$-7 \\ -6$	-8 - 7	—10 — 9	-12 -10	-14 -12	—16 —14	18 16	21 18	24 21	—28 — 24	3 2 28
+ 1	403	± 0	- 1	- 3 - 2 - 1	$\begin{bmatrix} -3 \\ -2 \end{bmatrix}$	- 4	- 6	- 7 - 6	9	—10 — 9	12 10	-14 -12	-16 -14	-19 -16	-22 -19	$-25 \\ -22$
2 3	444	2	一 1 ± 0 + 1	± 0	— 1	-3 -2	- 4 - 3	- 4	-6	— .7	9	-10	-12	-14	16	<u>22</u>
4 5	467 0.0491		± 0 + 1 2 3	$+ \frac{1}{2}$	± 0 + 1	— 1 ± 0	— 2 — 1	— 3 — 2	-6 -5 -2 -1 +1 -3 5	— 8 — 5	-7	— 9 — 7	—10 — 9	—12 —10	-14 12	16 14
6 7	515	5	4		2	± 0 + 1 2	± 0 + 1		- ž	— 3	- š	— 6	— 7	- 9	-10	—12
8	570	7	5 6	4 6	3 5	4	3	一 1 士 0 十 2	 + 1	— 2 — 1	$-3 \\ -2$	— 4 — 3	$ \frac{0}{4}$	- 5	— 9 — 7	—10 — 8
9 10	600 0.0631	8 9	7 9	7 8	6 7	5 6	4 5	1 3	2	$+\frac{1}{2}$	± 0 + 1	一 1 ± 0	— 3 — 1	-4 -2	- 5 - 4	— 7 — 5
11	665	10	10	9	8 9	7	6	5	5	4	3	± 0 + 1 3	± 0 + 2	1	- 2	— 3 — 2
12 13	735	11 12	11 12	10 11	10	8 10	8 9	8	7	5 6	4 5 7	4	3		- 2 ± 0 + 1 3	
14 15		13	13 14	12 13	11 12	11 12	10 11	10	8	8 9	7	6 7	5 6	4 5	3 4	± 0 2 3 5 6 8
16 17	850	15	15	14	13	13	12	11	11	10	9	8	8	7	6	5
18	933	16 17	16 17	15 16	14 16	14 15	13 14	13 14	13	11 12	10 12	10 11	9 10	8 9	7	5 8
19	0.0979 0.1026	18 19	18 19	17 18	17 18	16 17	15 16		14	13 15	13 14	12 13	11 12	11 12	10 11	9 10
	3.1020	10	10	10	10		A U		10	10	12	10	12	12		

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT Continued Pressure = 23.0 inches of mercury

Air			De	pres	sion	of w	et-b	ulb t	hern	nome	ter	(t -	<i>t'</i>).		
temp., t	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0
-2 -1	49 40		1												
0 +1 2 3 4	-33 29 25 22 19	-3 -2 -2	3 —42 9 —34 5 —29	-54 -43 -34	—56 —43 —35	58	— 59								
5 6 7 8 9	—17 —14 —12 —10 — 8	-1' -1'	16 2 —14	-22 -19 -16	29 25 22 19 16	-30 -25 -22	-45 -35 -30 -25 -21	60 45 35 29 25	60 45 35 29	45 35	11	60			
10 11 12 13 14	- 6 - 5 - 3 - 1 ± 0	- 6 - 4 - 2	- 7 - 5	-12 - 9 - 7 - 5 - 3	-14 -11 - 9 - 7 - 5	—11 — 8	—18 —15 —13 —10 — 8	-18 -15 -12	-24 -20 -17 -14 -11	29 24 20 17 13	—34 —28 —23 —19 —16	-43 -33 -27 -22 -18	59 42 32 26 21	56 40 31 25	53 38 29
15 16 17 18 19	+ 2 4 5 7 8	+ 1	+ 2 3 5	- 1 + 0 + 2 4 5	- 3 - 1 + 1 3 4	- 2 ± 0	- 5 - 3 - 2 ± 0 + 2	— 5 — 3	- 9 - 6 - 4 - 2 ± 0	一 8 一 5	-13 -10 - 7 - 5 - 3	15 12 9 6 4	-14 11	-20 -16 -13 -10 - 7	-24 -19 -15 -12 - 9
20	9	8	8	7	6	5	4	3	+ 2	+ 1	- 1	_ 2	— s	<u> </u>	<u> </u>
							(t -	- t)			•				
		t	6.2	3.4	3.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0			
		13 14		-47											
		15 16 17 18 19	-28 - -22 - -18 - -14 - -11 -	-34 -27 -21 -17 -13	-44 -32 -25 -20 -16	-59 -40 -29 -23 -18	-53 -36 -27 -21	-47 -33 -25	-42 -30	-58 -37 -	-49		,		
	[20	— 8 -	-10 -	-12	-14	-17-	-20 -	-23 -	-28	-33 -	-44			

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Continued

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Continued Pressure = 23.0 inches of insecury

	Pressure = 23.0 inches of mercury Depression of wet-bulb thermometer $(t - t')$
Vapor press.,	8.5 9 8 8 5 10.0 10 5 11.0 1 6 12.0 12 5 13.0 13.5 14.0 14.5 15.0 15.5 16
22 0.118 23 0.118 24 0.124 25 0.130 27 0.143 28 0.150 29 0.157 28 0.150 29 0.157 28 0.180 33 0.187 38 0.228 38 0.288 38 0.288 38 0.388 38 0.482	-28 -50

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Continued

~				Pr	essu	re =	23.	0 inc	hes c	of m	ercu	У		,		
				Dep	ressi	on o	f we	t-bul	b the	ermo	omet	er (t	-t')		
Air temp.	16.5	17.0	17.5	18.0	18.	19.0	19.	20.0	20.5	5 21.	021.	5 22.0	22.5	23.0	23.5	24.0
44 45 46 47 48 49 50 51 53 55 55 56 67 68 67 77 77 77 77 77 77 77 77 77 77 77 77	-29 -18 -11 -5 -11 +6 9 111 14 16 18 20 22 23 25 27 28 30 32 33 35 36 38 39 41 42 44 45 46 48 49 50 50 50 50 50 50 50 50 50 50 50 50 50	-31 -19 -11 -5 -11 +36 91 113 168 202 224 255 27 288 302 323 335 341 422 444 45	-20 -12 -6 -11 +2 -13 -14 -16 -18 -18 -20 -22 -24 -25 -27 -29 -30 -32 -33 -41 -43 -44	-35 -20 -12 -6 -20 -12 -16 -20 -11 -14 -16 -18 -20 -22 -24 -26 -27 -29 -31 -35 -37 -38 -40 -42 -43 -45 -46 -47 -49 -50 -49 -49 -49 -49 -49 -49 -49 -49 -49 -49	-38 -21 -12 -6 -21 -6 -8 -11 -14 -16 -18 -20 -22 -24 -26 -28 -29 -31 -32 -34 -36 -37 -39 -40 -42 -43 -45 -46 -48 -49	-40 -21 -12 -7 -27 +5 811 14 16 18 20 22 24 26 28 29 31 34 42 44 45 47 48 50	-42 -22 -13 -7 -7 -2 +2 5 8 11 14 16 18 20 22 24 26 28 30 31 33 35 36 38 40	-44 -22 -14 -7 -7 -2 +2 -7 -4 -7 -1 -7 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	-23 -14 -7 -2 +2 -5 9 11 14 17 19 21 23 25 27 28 30 32 34 35	-4 -2 -1 -3 + -3 + -3 -1 -3 -1 -3 -1 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3	1	-55 -26 -26 -15 - 8 - 3 + 6 9 12 15 17 19 22 24 26 27 29 31 33 40 41 43	-60 -26 -15 -8 -3 +2 -9 12 15 17 20 22 24 28 29 31 33 35 37 38 40 42	-27 -16 -8 -3 +2 9 12 15 18 20 22 24 26 28 30 32 34 35 37	-28 -16 -16 -17 -18 -17 -18 -18 -18 -18 -18 -18 -18 -18 -18 -18	-28 -18 - 6 - 3 + 2
				l	<u> </u>			l		1	<u>. </u>	er (t				
ŧ	24 .5	25.0											30.5		31.5	32.0
61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 79 80	-29 -16 -8 -2 +7 10 13 16 18 21 23 25 27 29 31 33 35 37 38	$\begin{array}{r} -29 \\ -16 \\ -7 \\ -2 \\ +3 \\ 10 \\ 13 \\ 16 \\ 19 \\ 21 \\ 23 \\ 26 \\ 29 \\ 31 \\ 33 \\ 35 \\ 37 \\ \end{array}$	$\begin{array}{r} -28 \\ -15 \\ -7 \\ -2 \\ +3 \\ 7 \\ 11 \\ 14 \\ 17 \\ 19 \\ 22 \\ 24 \\ 26 \\ 28 \\ 30 \\ 32 \\ 33 \\ 35 \end{array}$	-28 -15 -7 -1 + 3 11 14 17 20 22 24 28 30 32	-28 -15 -7 -1 + 8 11 14 17 20 22 24 27 29 31	-27 -14 -6 -12 12 15 18 20 23 25 27	$ \begin{array}{r} -27 \\ -14 \\ -6 \\ \pm 9 \\ 12 \\ 15 \\ 18 \\ 21 \\ 23 \\ 25 \\ 27 \\ 29 \\ \end{array} $	$ \begin{array}{c} -26 \\ -13 \\ -5 \\ \pm 0 \\ +5 \\ 9 \\ 12 \end{array} $	$ \begin{array}{r} -25 \\ -13 \\ -5 \\ +16 \\ 10 \\ 13 \\ 16 \\ 19 \\ 21 \\ 24 \\ 26 \end{array} $	-24 -12 - 4 + 1 6 10 13 16 19 22 24	76 77 78 79 80 -23 -11 -4 + 2 10 14 17 20	$ \begin{array}{c c} & & & \\ & 32.5 \\ & 32.5 \\ & & 32.5 \\ & & & & \\ & & & & \\ & & & & \\ & & & &$	$ \begin{vmatrix} $	- t'	-26 -11 -18 -8 -1	

TEMPERATURE OF DEW-POINT IN DEGREES FARRENHEIT. Continued Freesure = 23 0 inches of mercury

Air Vermp.		Depression of wet-bulb thermometer (= l')															
80 1 022 79 77 76 75 73 72 71 69 68 60 60 60 60 77 76 75 73 72 70 69 69 66 60 60 60 77 76 75 77 76 73 72 70 69 60 66 66 60 60 60 77 76 75 77 77 77 77 77	Air temp. t	2.5			. 121			-		171411	, , , , ,		14 (11)			. ,	
80	and or map !	1 5	ı	2	3	4	5	6	-	b,	9	11 0.	12	13	14	15	16
81 1.056 50 78 77 78 77 78 77 78 77 78 77 78 77 78 77 78 77 78 77 78 77 78 77 78 78 78 77 78	80		1.79	77	76	75	231	72	71	64	15 H	661.6	63	62	file	5%	53
82							73									80	
1 143 13 13 142 140 174 175 175 174 177 176 176 176 176 177 17		1.091	51	79		77	7.6			71	70		66	64		A1	51
1 201			No.						74	-	71	To 65	67	47	54	6.	- 60
1,241 S.S. S.A. S.Z. S.J. S.J. S.J. S.J. S.J. S.J. S.J											72				85	43	- 63
1 2 1 2 1									16								63
1 322 8 86 84 82 82 80 79 79 73 72 71 70 70 70 70 70 77 77										. 2						66	
1										-1							63
1																65	60
1 433 96 89 87 88 85 84 82 81 80 78 77 78 74 75 76 74 75 76 75 75														73		70	65
1 499 9 90 80 88 87 86 84 83 82 81 79 76 74 75 76 74 75 76 74 75 76 74 75 76 74 75 76 76 76 76 76 76 76	03	1 453	W	H SJ	87		N 5	54								71	70
1546 92 91 90 80 80 83 83 82 8 77 78 78 78 78 78		1 499	91	90	la No	47			84	N2	×1	730 "4				7.3	71
16 16 16 16 16 17 17 17											82		7%	76	73	74	72
1 696 45 94 92 91 90 80 88 86 85 84 84 87 80 75 70 96 94 97 98 94 97 96 94 97 96 94 97 96 94 97 96 94 97 96 94 97 96 94 97 96 94 97 96 94 97 96 96 97 96 96 97 96 96												B. 4	7.9			7.5	71
1																76	74
1 803 77 26 24 37 91 1 90 88 87 86 83 82 91 100 1 916 26 58 27 94 89 90 89 88 87 86 84 83 82 91 101 1 1.975 7 8 96 96 96 97 94 97 94 97 96 1 96 96 88 88 88 88 88 88																	76
1.859			100			11.7		-								- 1	77
109 1 916 Pr Qr 96 97 94 3 9 90 89 88 87 82 84 83 80								97								hú	1
103			314	ten.	96											h]	NO
100		1.975	TH	$\mathbf{Q}\mathbf{Q}$	40	AD.	97	164	Q.T.	40	40		45			N 3	01
100					94	9			40.6	41		27 hz	B, s,	10%	-	há	83
186					E,	50%							R-d	4"		45	NJ
107 108 109 109 109 109 109 109 109 109 109 109			1	10	-1									47.		36	8.5
107 108 109 109 109 109 109 109 109 109 109 109		2 223		N N												*	Bd
100			-													44	147 Rej
100		2 411														90	N9
113				07	g.	14	10'00									4	90
113	110	2 576	30	10%	417	l.	14.	-	٠.	-1	1.8	ton u"	96		94	92	91
113						-	H .		L				97	H.		91	93
116	112	2 1 10		, 1)		115	M.M.		-H							94	93
116 117 13 148 118 13 239 17 118 1 4 2'	114	2 891		11	1	- 41			-						-	97	94
116 117 13 148 116 115 114 117 13 148 116 115 114 117 13 148 118 13 239 17 117 14 17 18 13 239 17 117 14 17 18 13 3.11 18 117 16 1 \$ 2	115	2 975			1		17-30	- Die	-					-		1.36	96
117 118 13 13 148 17 119 13 13 141 17 119 13 13 141 17 18 17 18 17 18 17 18 18 17 18 17 18 18 17 18 18 17 18 18 18 18 18 18 18 18 18 18 18 18 18			115	114	1			09	N()	-	м	- 1	N.			gen	97
\$ 110			116	[15]°	114		1	-	7	1 %		Nat				žūs	99
\$ 4.25				115.0	4	4	2						ь М	-	-61,		100
121					14	1						4	-0	- 4	-L	45,	01
122 123 124 125 126 126 127 128 128 129 129 129 120 120 120 120 120 120 120 120 120 120]	. '	-					. **	-		-	- 115	102
128						11.								M.	F).	-14	104
194		7 7		Jir.							16	, , , ,	-		-	1-95	
127 128 4 26N 527 26 27 130 4 385 8 26 28 130 4 385 130 4 386 130 131 14 627 15 130 16 627 17 130 18 18 18 18 18 18 18 18 18 18 18 18 18 1	194	3 827		2		М					- 6			,	150	-	
127 128 4 26N 527 26 27 130 4 385 8 26 28 130 4 385 130 4 386 130 131 14 627 15 130 16 627 17 130 18 18 18 18 18 18 18 18 18 18 18 18 18 1	135	3 913	4	-1-			24.1	-	1	+		421	1				
128	135	4 012		-4					, to	17	4	114	11				
130 4 385		4 1/54		-	.4			4	,			1 1981					109
131 4 627 8 1261 8 4 1 1 1 2 6 6 1 1 6 6 6 6 6 6	596				*	,		•	79		"					11	
131 4 627 8 1261 8 4 1 1 1 2 6 6 1 1 6 6 6 6 6 6	230	1 414		124	,		• '										111
133 4 880 7 161 7 7 4 7 8 1 8 1 8 1 8 1 8 1 8 1 8 1 8 1 8 1 8					. 4		No.	4.3					1.	1.			113
195 5 145 14 1 1 1 1 1 1 1 1	132	4.732			H,	-	20		-4					14		-	
195 5 145 14 1 1 1 1 1 1 1 1	133	4 850	1	11.1						- 6		1.					
136 5 % 7 5 4 7 7 7 7 7 7 7 7 7			ķ	1 1		W	N PE	*			- 6		2	,h			116
187 5 422 66 1 4 17 122	135	1 245						•					-		_		_
198 L 685 107 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1				,	,			A	-				,				114
						1.0											120
1 th and the second sec																	121
3.362 1139 138 137 136 135(134 133 131 130 29 128 127 126 125 12			139 1	38 1	37	36	35(1	34 1	33	31 1	130						

92 METALLURGISTS AND CHEMISTS' HANDBOOK

TEMPERATURE OF DEW-POINT IN DEGREES FARRENBEIT, Continued

Premure = 23 0 inches of mercury

A.s.	F .		1	Dep		поп	_	_		lb t	_	mo	met	er (t -	ť)	
Air temp, t	Vapor press	17	18	19	20	21	22	23	24	25	26	27	28	29	30	ш	32
90	1 022	- 45			49			42	41	37	34	31	, 28	24	20	15	-
80 81	1 056			52	50	48		44	41	39	34	Ph			23		
82	091	57	55	54	52	50		45	43		38	_		29			
63	1 127	39		55	53	51	49	47	44	42	408		34	31	27		
84	1 163	60		56	54	52		45	46		41	39					
8.5	1 201	61	59	58	56	54	52	50	48	45	43			35		28	
86	1 241	62						51	41/	47	45	42	40		34	30	
67	1 281	64		60	58	57		53	51	48	46			39			
88	1 322	65	63	61	60	5×		54	52	50	48						
89	1 364	66	2 1	63	61	59		55	54	52	49		45				
10	1 408		66	64	62	6(1		57	55	53	51	49	48		41	38	
91	1 453			65	63	62		5 h	56		52	50	48				
92	1 499	_	10.0	66	6.5	6.3		59	48	56	54	52			45		
93	1 546	_	69	68	56	84		61	5.1	57	5.5	53	51	49			1 2
94	1 595	72	70	69	67	66		63	60	59	57	55	53	50			
95	1 645	73	72	70	68	67	55	63	62	60	5×		54	52			
	T	74	73	71	70	5A		65	6.1	61	60		56		51	49	
95	1 695 1 449	75	74	72	źi	60					61		57			51	
97		76	75	74	72			67	66	6.1		59		55			
98	1 803	75	76		73	70	76		67	64	62	60	5.4	56		52	
99	1 859 1 916	79	77	75 76		72		70		65	64	62	60				
100		2.7	7%	77	74	73 74	71 73	21	Bh	67	65		61	59			
101	1 975	80			76	1.5			69	BH.	67		63	61	59		
102	2 035	81	80	74		75	74	72	71	69		66		62			
103	2 097	82	81	79	78	76	75	73	73	70	69		65	64	62		
104	2 150	K3	H-2	60	79	75		25	71	72	70	6H	67	65	63		6
105	2 225	84	×3	82	R/A	70		75	74	73	Ē1,	70	. 6×	66		63	
106	2 292	R5	N-E	83	81	80		77	70	74	72	71	69		06		
107	2 360	86	55	84	82	N.I.	80	78	77	75	7.5	7.1	71	69		66	
108	2 431	88	88	85	54	62	81	79	74	76	15	73	72	70			_
109	2 503	SQ.	MZ	Act	85	83	R2	81	79	78	75	75	23	72	70		
110	2 575	90	Bh	87	86	84	N3	12	N. C.	79	741	76	1.7	73	71	69	
111	2 652	0.0	90	RN	A ⁿ	46	44	N.S	81	N ₁ ×	79	77	26	74	72	71	
112	2 730	92	91	89	58	h."	85	14	A.3	81	50	78	77	75	74	72	
113	2 810	93	92	90	59	No.		55	24	82	81	H	78	76	75	73	
114	2 691	94	93	92	90	8 1		80	3.5	84	82	NI	79	78	76	75	
118	2 975	95	94	93	91	90	2.1	87	86	85	83	82	80	79	77	76	
116	8 061	IIId	95	94	92	91	94	89	57	86	84	83	72	80	79	77	
117	3 148	97	96	95	94	93	[4]	H	hh	N7	56	14	h.3	81	80	78	
118	3 239	lij8	97	26	95	93	65	91	59	St N	87	N.5	84	83	81	80	
119	3 331	99	94	97	96	46	93	92	90	89	84	N .	MS	h4	82	81	7
120	3 425	101	Ph	98	6.	95		97	42	90	33	RN	14 fi	8.5	84	82	
121	3 522	1 -	I E M	99	98	47	5.5	94	163	02	Bell		35	N.S.	85	83	
122	3 621	1-3		100	99	940		95	94	11.3	91	94	140	87	86		
123	3 723		1 10		100	914		96	95	14	92	91	91	85	87	86	
124	3 827	1 15	1 14	102		100		97	11 Th	95		92	9.	90	88	87	8
125	3 933		105	103	105	101	10	50	97	96	95	93	92	91	89	88	
128	4 042	1 7	1 10	1 14	. E	12		1 161	a fac	9.7	상다	95	93	69	91	89	8
127	4 154	1 5	17	100	14		1 1	1.1	98		9"	96	94	93	92	90	8
128	4 268		1.05	102	1 7	1 14		! .	1 7	şiü	84	64	95	94	93	b to	9
129	4 385		109	108	1111	1 57	1 14	143	1 7	1 4	99	1-5	97	95	94	93	II.
130	4 504	111	110	, 19	14 %	1 W	1 5	111	14	IC.	H 1	99	1 %	916	95	94	9:
13 L	4 627	112	111	110	Likh	1.7	106		104			701	101	94	96	95	9
132	4 752		115	.11	· It	-	7 111		lto.				1.6	θë	97	95	
133	4 5NI		1 3	112	111	11	to the		[07				101		90	97	II.
134	5 (11	315	111	1 1 3	113	111	[Ha	Pylin	7	Fret.	165					98	
185	5 145	216	115	14	11)	112	Ш	N1	1.34				1 K.		1 1	99	0:
136	5 282	117	114	115	114	11 1	112	0] H)	1 14		1 14	1 14			101	9
137	5 422		17	116				111	11+	1 8	19		1 5			102	
138	5 565	7.0	HK.	.17		115		112	111	11						103	
139	5 712					116							108				
140	5 862	171	190	119	11K	117	116	135	113	112	1111	110	109	108	106	105	104

TEMPERATURE OF DEW-POINT IN DEGREES FAHRENHEIT. Concluded Pressure = 23.0 inches of mercury

Air mp., f	01 8 . 6]	Эері	essio	n of	wet	-bal	b th	ermo	met	er (£	t')	
Air temp.,	Vapor	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
	1 022 1 056	1 6		—21								1		- ,t	ť)	
82	1,091 1 127	11 14	+ 3	_ g	-171								49	50	51	52	53
84 85	1 163 1.201	18, 21		+ 6	+ 1	30 -13				Ì		104	20 6	-40			
86 87	1 241 1,281	23 26	19 22	13	6.	+ 3	-23 -10	_54				106 107	+ 3	-12	-23		
68 .	$\frac{1}{1},\frac{322}{364}$	28 30	24 27	20 23	15 18	12	- 1-	-18	_34			108 109	14 19	-8 12	- 6	49 —14	
90 91	1 408 1 453	32 34	29 31	25 28	21 24	16 20	10 14		-14 - 3	- 25		110	22	17	9		-25
92 93	1,499 1 546	36 39	33 36	30 32	27 29	23 25	18 21	11 - 15 ₁		- 9	-59 17						
94 95	1 595 1 645	41	38 40	35 37	31 33	28 30	24 26	19	13 17	+ 6 11	$+\frac{5}{2}$	32°					
96	1 696 1 749		42 44	39 41	36 38	32 34	29 31	25	20	15, 19,	13	_ 2	-22 - 7	41			
98	1 803 1 859	48	45 47	43 45	40	37 39	33. 36.	30	26 29	22 25	17 21	10 14	7	—15 — 3	-28		
100 101	1 916 1 975	51 53	49 51	46 48	44	41 43	38- 40-	35 37	31	28 30	24 26	19 22	17	+ 4 10	± 6	18	
102	2 035 2 097	54 56	52 54	50 52	48	45	42 44.	39. 41	36 38	32 35	29 31	25 28	20 23	14	+ 7	- 5 + 3	-32 11
104 105	2 035 2 097 2 160 2 225 2 292 2 360 2 431 2 503 2 576	57 59	55 57	53 55	51 ¹	49 56	46 48	43 45	40 42	37 39	34 36		26 29	22 ¹ 25	18 20	14	+ 6
106 107	2 292 2 360	60	58 60	56 58	54 56	52 54	50 51	47	46	42	39	38	32 34	28 31	24 27	18 22	12 16
108 109	2 431 2 503	63 65	61 63	59 61	57' 59	55 57	53 55	51 53	48 50	48	43 45	40 42	37 39	33 36	29 32	25 28	20 24
110 111	2 652	66 67	64 66	62 64	60· 62	58 60	58	54 56	52 54	50 51	47		411	38 40	34 37	31 33	27 30
113	2.810	70	67 68	65 67	63 65	63	61	57 59	55 57	53 55	51 52		46 48	43	40 42	36 38	32 35
114	$\frac{2.891}{2.975}$		70 71	68 69	66	66		61 62	59 60	56 58	54 56	54	49 61	49	44	43	38 40
116 117	3 061 3 148	74 75	72 74	71 72	69 70	67 69		64	63	60	59	57	53 55	50 52	48 50	45; 47	42 44
118 119	3 239 3.331	77	75 76		72 73	70 71	70	67 68	85 66	63 64	61 62		57 58	54 56	52 54	49; 51	49
120 121	3 425 3 522	79 80	78 79	77	74 76	73 74	71 72	69 ₁	68 69	66	65	63	60 61	58 59	55 57	53 55	50 52
123	3 621 3 723	83	81	80	78	75 77	75	72 74	70 72	69. 70	68	66	63 64	61 63	59 61	58	54 56
124 125	3 827 3.933	84 85	83 84	81 82	80 81	78 79	76 78	75 76	73 74	72 73	70 71	69	66	64 66	62 64	60 62	58 60
126 127	3 723 3 827 3 933 4 042 4 154 4 268 4 385	88	85 86	84 85	82 83	81 82	79. 80	78. 79,	76 77	74 76	72 74	71 72	69 70	67 69	65 67		61 63
128	4 288 4 385	90	87 89	86 87	85 86	83 84	83:	80i 81	78 80	77 78	75 77	75	72 73	70 72	68 70	68	68
130	4 504 4 627	92	90 91	90	87 88	86 87	85	83: 84	81 82	80°	79	78.	75 76	73 74	71 72	69, 71	68 69
124 125 126 127 128 129 130 131 132 133 134 136 136 137	4 752 4 880 5 011 5 145 5 282	93 95	92 93	91 92	89 91	88 89	88!	85 86	84 85	82 83	81 82	79 80	77 79	76 77	74 75 77	72 74 75	70 72 73
136	5 011 5 145	97	94 96	93 94	92 93	90 92	90	88	86 87	85°	83 84	83,	80	78 80	78	76	75 76
135	5 282 5 422 5 565	98	97 98	95 97	94 95	93 94	93	90	89 90	87 88	86 87	85	83 84	81 82 84	80 81	78 79	78 79
139	15.712	301	100	98	96 98	95 96	94 95	92 94	91 92	90 91	88 89	88	85 86 88	84 85 86	82 83 85	81 82, 83]	80 81
140	5.862	103	101	100	99	97	96	95	93	92	91	89	60	00	00	00	94

RELATIVE HUMIDITY, PER CENT.—FAHRENHEIT TEMPERATURES Pressure = 30.0 inches of mercury

Air	Depression of wet-bulb thermometer $(t - t')$
temp,	0.2 0.4 0 6 0.8 1 01 2 1.4 1.6 1.8 2 02 2 2 4 2.6 2.8,3.0 3.2 3 4 3.6 3 8 4.0
-40 -39	46 48 50 0 4 2 4 4 4 6 4 8 5 .0 6 2 5 4 5 6.5 .8 6.0
- 38 - 37 - 36 - 35 - 34 - 32 - 31 - 30 - 29 - 28 - 25 - 24	50 2 53 6 56 10 59 15 61 20' 63 24' 64 28' 66 32 68 36 4 29 70 41 9 5 13 10 15 21 18 34 17 3 27 24 21 16 28 24 21 18 14 18 15 25 21 18 14 18 15 27 24 21 17 3 27 24 21 17 14 11 15 27 24 21 27 24 20 37 34 32 29 5 20 37 34 32 29 26 23 20 20 37 34 32 29 26 23 <
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+ 2 3 4 6 6 7 8 9 10 11 2 13 14 15 16 7 18 9 20 19 20 19 19 19 19 19 19 19 19 19 19 19 19 19	93 87 80 73 67 60 53 47 40 33 27 20 14 7 1 93 87 81 75 68 62 56 49 43 36 30 24 18 11 5 9 3 94 88 82 76 70 64 58 52 46 39 33 27 21 15 9 3 94 88 82 77 71 65 59 54 48 42 36 30 25 19 13 7 2 94 89 83 78 72 66 (1 55 50 44 39 33 28 22 17 11 6 0 95 89 84 78 73 68 63 57 52 46 41 36 31 25 20 15 10 4 95 90 84 79 74 69 64 59 54 49 43 38 33 28 23 18 13 8 3 95 90 86 81 76 71 67 66 60 55 51 46 41 36 31 26 21 17 12 7 2 95 90 86 81 76 71 67 66 65 57 53 48 43 38 34 29 24 20 15 11 6 95 91 86 82 77 72 68 63 59 55 54 46 41 36 31 26 21 17 12 7 2 95 90 86 87 77 72 68 63 59 55 54 46 41 36 32 27 23 18 14 10 96 91 87 82 78 73 69 65 60 56 52 47 43 39 34 30 26 22 17 13 96 91 87 83 79 74 70 66 62 58 53 49 45 41 37 33 28 25 20 16 96 92 88 84 80 75 71 67 63 59 55 51 47 43 39 35 31 27 23 19 96 92 88 84 80 75 71 67 63 59 55 51 47 43 39 35 31 27 23 19 96 92 88 84 80 75 71 67 63 59 55 51 47 43 39 35 31 27 23 19 96 92 88 84 80 75 71 67 63 59 55 51 47 43 39 35 31 27 23 19 96 92 88 84 80 76 73 69 65 61 57 53 49 45 41 38 34 30 26 23 96 92 89 85 81 77 74 70 66 62 59 55 51 48 44 40 37 33 29 26 96 93 80 86 82 78 75 71 67 64 60 57 53 50 46 42 39 35 32 29 96 93 90 86 82 78 75 71 67 64 60 57 53 50 46 42 39 35 32 29 96 93 90 86 82 78 75 71 67 64 60 57 53 50 46 42 39 35 32 29 96 93 90 86 82 78 75 71 67 64 60 57 53 50 46 42 39 35 32 29 96 93 90 86 82 78 75 71 67 64 60 57 53 50 46 42 39 35 32 29 96 93 90 86 82 78 75 71 67 64 60 57 53 50 46 42 39 35 32 29 96 93 90 86 82 78 75 71 67 64 60 57 53 50 47 43 40 37 34 97 93 90 86 83 80 77 74 71 68 65 61 58 55 52 49 45 42 39 36 97 94 90 87 84 81 78 75 72 69 66 63 60 56 53 50 47 44 41 38 97 94 90 87 84 81 78 75 72 69 66 63 60 56 53 50 47 44 41 38 97 94 90 87 84 81 78 75 72 69 66 63 60 58 53 50 47 44 41 38 97 94 91 88 85 82 79 76 73 70 67 64 61 58 55 52 49 45 42 39

RELATIVE HUMIDITT, PER CENT.—FARRENBEIT THEFERATURES. Continued Pressure = 30.0 inches of mercury

RELATIVE HUMIDITY, PER CENT.—FAHRENHEIT TEMPERATURES. Continued

Pressure = 30.0 inches of mercury

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257025508912456789901234444444455555555555555555555555555555

RELATIVE HUMIDITY, PER CENT.—FAHRENHEIT TEMPERATURES.

Continued

Pressure =	30.0	inches of	mercury
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			Der	ressi	on c	f we	t-bu	lb th	erm	ome	ter (t — 1	!')		
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Air	Depression of wet-bulb thermometer $(t-t')$														
temp., t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
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82	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45
84	96	92	88	84	80	76	73	69	66	62	59	56	52	49	46
86	96	92	88	84	81	77	73	70	66	63	60	57	53	50	47
88	96	92	88	85	81	77	74	70	67	64	61	57	54	51	48
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49
92	96	92	89	85	82	78	75	72	68	65	62	59	56	53	50
. 94	96	93	89	85	82	79	75	72	69	66	63	60	57	54	51
96	96	93	89	86	82	79	76	73	69	66	63	61	58	55	52
98	96	93	89	86	83	79	76	73	70	67	64	61	58	56	53
100 102	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54
102	96	93	90	86	83	80	77	74	71	68	65	62	60	57	55
104	97	93	90	87	83	80	77	74	71	69	66	63	60	58	55
106 108	97	93	90	87	84	81	78	75	72	69	66	64	61	58	56
108	97	93	90	87	84	81	78	75	72	70	67	64	62	59	57
110	97 97	93	90	87	84	81	78	75	73	70	67	65	62	60	57
112 114	97	94 94	90 91	87	84	81	79 7 9	76 76	73 74	70 71	68 68	65 66	63	60	58
11 2 118	97	94	91	88 88	85 85	82 82	79	76	74	71	69	66	63	61	58
116 118	97	94	91	88	85	82	79	77	74	72	69	67	64	62	59 59
120	97	94	91	88	85	82	80	77	74	72	69	67	64	62	60
120	97	94	91	88	85	83	80	77	75	72	70	67	65 65	63	60
124	97	94	91	88	85	83	80	78	75	73	70	68	65	63	61
128	97	94	91	88	86	83	80	78	75	73	7ŏ	68	66	64	61
128	97	94	91	89	86	83	81	78	76	73	71	68	66	64	62
130	97	94	91	89	86	83	81	78	76	73	71	69	67	64	62
120 122 124 126 128 130 132	97	94	92	89	86	84	81	79	76	74	71	69	67	65	63
134	97	94	92	89	86	84	81	79	76	74	72	69	67	65	63
136	97	94	92	89	86	84	81	79	77	74	72	70	68	65	63
138	97	94	92	89	87	84	82	79	77	75	72	7Ŏ	68	66	64
140	97	95	92	89	87	84	82	79	77	75	73	70	68	66	64

RELATIVE HUMIDITY, PER CENT.—FAHRENHEIT TEMPERATURES. Continued Pressure = 30.0 inches of mercury

				CBB (L)			OIMG								
ŧ			D	epre	86 101	of	wet-l	bulb	ther	mon	eter	(t -	· t')		
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
80	41	38	35	32	29	26	23	20	1 18	15	112	10	7	5	8
82	42	39	36	33	30	28	25	22	20	17	14	12	10	7	3 5 7
84	43	40	37	35	32	29	26	24	21	19	16	14	12	9	
82 84 86	44	42	39	36	33	31	28	26	23	21	18	16	14	11	9
88	46	43	40	37	35	32	30	27	25	22	20	18	15	13	11
90	47	44	41	39	36	34	31	29	26	24	22	19	17	15	13
92	48	45	42	40	37	35	32	30	28	25	23	21	19	17	15
94.	49	46	43	41	38	36	33	31	29	27	24	22	20	18	16
96 98 100 102 104	50	47	44	42	39	37	35	32	30	28	26	24	22	20	18
98	50	48	45	43	40	38	36	34	32	29	27	25	23	21	19
100	51	49	46	44	41	39	37	35	33	80	28	26	24	22	21
102	52	49	47	45	42	40	38	36	34	32	30	28	26	24	22
104	53	50	48	46	43	41	39	37	35	33	31	29	27	25	23
106	53	51	49	46	44	42	40	38	36	34	32	30	28	26	24
108	54	52	49	47	45	43	41	39	37	35	33	31	29	27	25
110	55	52	50	48	46	44	42	40	38	36	34	32	30	28	26
112	55	53	51	49	47	44	42	40	38	36	35	33	31	29	27
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116	57	54	52	50	48	46	44	42	40	38	36	34	33	31	29
118	57	55	53	51	49	47	45	43	41	39	37	35	34	32	30
120	58	55	53	51	49	47	45	43	41	40	38	36	34	33	31
122	58	56	54	52	50	48	46	44	42	40	39	37	35	34	32
124	59	57	54	52	50	48	47	45	43	41	39	38	36	34	33
120	59	57	55	53	51	49	47	45	44	42	40	38	37	35	33
128	60	58	56	54	52	50	48	46	44	42	41	39	37	36	34
130	60	58	56	54	52	50	48	47	45	43	41	40	38	37	35
132	61	58	56	55	53	51	49	47	45	44	42	40	39	37	36
134	61	59	57	55	53	51	49	48	46	44	43	41	39	38	36
136	61	59	57	55	54	52	50	48	46	45	43	41	40	38	37
138 140	62	60	58	56	54	52	50	49	47	45	44	42	40	39	37
140	62	60	58	56	54	53	51	49	47	46	44	43	41	40	38

wet bulb are found to agree very closely, thereby showing that it has reached its lowest temperature. A minute or more is

generally required to secure the correct temperature. When the air temperature is near the freezing point it often

happens that the temperature of the wet bulb will fall several degrees below freezing point, but the water will still remain in the liquid state. No error results from this, provided the minimum temperature is reached. If, however, as frequently happens, the water suddenly freezes, a large amount of heat is liberated, and the temperature of the wet bulb immediately becomes 32°. In such cases it is necessary to continue the whirling until the ice-covered bulb has reached a minimum temperature.

The psychrometer will give fairly accurate indications, even in the sunshine, yet observations so made are not without some error, and where greater accuracy is desired, the psy-

chrometer should be whirled in the shade.

[While the above is true for refined observations, such as were necessary in Professor Marvin's work, yet for practical work I have found that a wet- and a dry-bulb thermometer, simply mounted on a board and placed in a good draft, would give accurate enough results for technical data. In this case the cloth wrapper of the wet-bulb thermometer went down into a cup of water, so that it was always wet and hence always ready for an observation. See also p. 104.—EDITOR.]

RELATIVE HUMIDITY, PER CENT.—FAHRENHEIT TEMPERATURES.

Continued
Pressure = 30.0 inches of mercury

Air			De	pres	sion	of v	vet-b	ulb (therr	nom	eter	(t -	<i>t'</i>)		
temp., t	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
80 82 84 86 88 90 92 94 96 98 100 102 104 106 110 112 114 116 118 120 122 124 126 128 130 132 134 136 138 140	0 2 5 7 9 11 13 14 16 17 19 20 21 22 4 25 26 27 28 29 29 30 31 32 33 33 34 35 35 36 37	0 3 5 7 9 11 12 14 15 7 18 20 1 22 23 4 25 27 28 29 30 31 32 33 34 35 35	0 3 5 7 9 10 124 15 16 18 19 20 1 23 24 25 26 27 28 29 30 31 32 33 34	1 3 5 7 9 10 12 13 15 16 17 19 20 1 22 23 24 25 26 27 28 29 30 31 32 32 32	1 3 5 7 8 10 12 13 14 16 17 18 19 20 22 23 24 25 26 27 28 29 30 31	1 3 5 7 8 10 11 13 14 16 17 8 19 20 1 22 23 4 25 26 27 28 8 29 30	1 3 5 7 8 10 11 13 14 15 16 18 19 21 22 22 24 25 26 27 28 29	135780112 112115 11215 11215 11215 11215 11215 1121	2357801124 1124156178190221222222222222222222222222222222222	0245781011121314161718818920122223232425	02457801121314516718922122234	1245789112131451671892021223	124578911234567889011231156788901221	134678911213145161718920	1 3 4 6 7 8 9 10 11 2 13 14 15 16 17 18 19 19
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136 138 140	17 17 18	16 16 17	15 15 16	14 14 15	13 14 14	12 13 13	11 12 12	10 11 12	9 10 11	8 9 10	7 8 9	6 7 8	6 7 7	5 6 7	4 5 6

RELATIVE HUMIDITY, PER CENT.—FAHRENHEIT TEMPERATURES. Continued

RELATIVE HUMIDITY, PER CENT.—FAHRENHEIT TEMPERATURES. Continued Pressure - 30.0 inches of mercury

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RELATIVE HUMIDITY, PER CENT.—FAHRENHEIT TEMPERATURES. Continued

RELATIVE HUMIDITY, PER CENT.—FAHRENHEIT TEMPERATURES.

Continued
Pressure = 23.0 inches of mercury

	$\frac{(t-t')}{22 23 24 25 26 27 28 29 30 31 32 33 34}$														
١	22	23	24	25	26	27	28	29	30	31	32	33	34		
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	25	22	19		114		10	7	ĥ	2 3 4	1				
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77		24	21		116		12	ğ	4 5 6 7	5	3	1	1		
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		26			119	17	15		10			4	2		

Air]	Depr	essic	n of	wet	-bull	o the	rmo	mete	er (t	-t')		
temp.,	1	2	3	4	5	6	7	8	9	10	11	12	12	14	15	16
		-		-			'			10		12	1 2 1			10
80	96	92	88	84	80	77	73	70	67	63	60	57	54	51	48	45
82	98	92	88	85	81	77	74	71	67	64	61	58	55	52	49	46
84	96	92	89	85	81	78	74	71	68	65	61	58	55	53	50	47
86	96	92	89	85	81	78	75	71	68	65	62	59	56	53	50	48
88	96	93	89	85	82	79	75	72	69	66	63	60	57	54	51	49
90	96	93	89	86	82	79	76	73	69	66	63	61	58	55	52	50
92	96	93	89	86	83	79	76	73	70	67	64	61	58	56	53	51
94	96	93	89	86	83	80	76	73	70	67	65	62	59	56	54	51
96	96	93	90	86	83	80	77	74	71	68	65	62	60	57	55	52
98	97	93	90	87	83	80	77	74	71	68	66	63	60	58	55	53
100	97	93	90	87	84	80	77	75	72	69	66	64	61	58	56	53
102	97	93	90	87	84	81	78	75	72	69	67	64	61	59	57	54
104	97	93	90	87	84	81	78	75	72	70	67	65	62	59	57	55
106	97	94	90	87	84	81	78	76	73	70	68	65	62	60	58	55
108	97	94	90	87	84	82	79 79	76	73	71 71	68	65 66	63	61 61	58 59	56 56
110	97 97	94 94	91 91	88 88	85 85	82 82	79	76 77	74 74	71	68 69	66	64	62	59	57
112 114	97	94	91	88	85	82	80	77	74	72	69	67	64	62	60	58
116	97	94	91	88	85	82	80	77	75	72	70	67	65	62	60	58
118	97	94	91	88	85	83	80	77	75	72	70	67	65	63	61	58
120	97	94	91	88	85	83	80	77	75	73	70	68	65	63	61.	59
122	97	94	91	89	86	83	80	78	75	73	71	68	66	64	62	59
124	97	94	91	89	86	83	81	78	76	73	71	68	66	64	62	60
126	97	94	91	89	86	83	81	78	76	74	71	69	67	65	62	60
128	97	94	91	89	86	84	81	79	76	74	72	69	67	65	63	61
130	97	94	92	89	86	84	81	79	76	74	72	70	67	65	63	61
132	97	94	92	89	86	84	81	79	77	74	72	7ŏ	68	66	63	61
134	97	95	92	89	87	84	82	79	77	75	72	7Ŏ	68	66	64	62
136	97	95	92	89	87	84	82	79	77	75	73	70	68	66	64	62
138	97	95	92	89	87	84	82	80	77	75	73	71	69	66	64	62
140	97	95	92	90	87	85	82	80	78	75	73	71	69	67	65	63

RELATIVE HUMIDITY, PER CENT.—FAHRENHEIT TEMPERATURES.

Continued
Pressure = 23.0 inches of mercury

-	Ī			Depr	essi	on of	wet	-bul	b the	rmo	met	er (t	- t')		
t	<u> </u>			1	1		1	1	1			1	1			
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
80	42	39	37	34	31	29	26	24	21	19	17	15	12	10	8	6
82	43	40	38	35	33	30	28	25	23	21	19	16	14	12	10	8
84	44	42	39	36	34	31	29	27	24	22	20	18	16	14	12	10
86	45	43	40	38	35	33	30	28.	26	24	22	20	17	15	13	12
88	46	44	41	39	36	34	32	29	27	25	23	21	19	17	15	13
90	47	45	42	40	37	35	33	31	28	26	24	22	20	18	17	15
92	48	46	43	41	38	36	34	32	30	28	26	24	22	20	18	16
94	49	46	44	42	39	37	35	33	31	29	27	25	23	21	19	18
96	50	47	45	43	40	38	36	34	32	30	28	26	24	22	21	19
98	50	48	46	43	41	39	37	35	33	31	29	27	25	24	22	20
100	51	49	46	44	42	40	38	36	34	32	30	28	26	25	23	21
102	52	50	47	45	43	41	39	37	35	33	31	29	27	26	24	22
104	52	50	48	46	44	42	40	38	36	34	32	30	28	27	25	23
106	53	51	49	47	44	42	40	38	37	35	33	31	29	28	26	24
108	54	51	49	47	45	48	41	39	37	36	34	32	30	29	27	25
110	54	52	50	48	46	44	42	40	38	36	35	33	31	30	28	26
112	55	53	51	48	46	45	43	41	39	37	35	34	32	30	29	27
114	55	53	51	49	47	45	43	41	40	38	36	34	33	31	30	28
116	56	54	52	50	48	46	44	42	40	39	37	35	34	32	30	29
118	56 57	54 55	52 53	50 51	48 49	46 47	45 45	43	41 42	39 40	38 38	36 37	34 35	33 33	31 32	30 30
120 122	57	55	53	51	49	48	46	43 44	42	41	39	37	36	34	33	31
124	58	56	54	52	50	48	46	45	43	41	39	38	36	35	33	32
126	58	56	54	52 52	50	49	47	45	43	42	40	39	37	35	34	33
128	59	57	55	53	51	49	47	46	44	42	41	39	38	36	35	33
130	59	57	55	53	51	50	48	46	45	43	41	40	38	37	35	34
132	59	57	56	54	52	50	48	47	45	43	42	40	39	37	36	34
134	60	58	56	54	52	51	49	47	46	44	42	41	39	38	36	35
136	60	58	56	55	53	51	49	48	46	44	43	41	40	38	37	36
138	61	59	57	55	53	51	50	48	46	45	43	42	40	39	37	36
140	61	59	57	55	54	52	50	49	47	45	44	42	41	39	38	37
130		LVV			. V Z	. 02		1 20		10	7.2	120			, 00	

In Coal Age there appeared the following simple formula for calculating humidities of the air from the ordinary hygrometer readings: this is:

$$100 - H = \frac{460}{d} (d - w)^{0.84}$$

in which d and w are the dry- and wet-bulb readings (Fahrenheit) and H is the percentage humidity. This formula requires logarithms, and is for sea-level. A simpler one can be devised to suit the underground conditions of the mines, where neither the temperature nor the humidity varies much.

RELATIVE HUMIDITY, PER CENT.—FAHRENHEIT TEMPERATURES.

Continued

Pressure = 23.0 inches of mercury

Air	Depression of wet-bulb thermometer $(t - t')$															
temp.,	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
80 82 84 86 88	4 6 8 11 11	2 4 6 8 10	0 2 4 6 8	0 2 4 6	1 2 4	1 3	1									
90 92 94 96 98	13 14 16 17 18	11 13 14 15 17	9 11 12 14 15	8 9 11 12 14	6 8 9 11 12	4 6 8 9 11	35689	1 3 5 6 8	2 3 5 6	0 2 3 5	0 2 4	1 2	0			
100 102 104 106 108	20 21 22 23 24	18 19 20 21 22	16 18 19 20 21	15 16 17 18 19	13 15 16 17 18	12 13 14 16 17	10 12 13 14 15	9 10 12 13 14	8 9 10 11 12	6 8 9 10 11	5 6 8 9 10	4 5 6 8 9	2 4 5 7 8	1 3 4 5 7	1 3 4 5	0 2 3 4
110 112 114 116 118	25 26 27 27 27 28	23 24 25 26 27	22 23 24 25 25	20 21 22 23 24	19 20 21 22 23	18 19 20 20 21	16 17 18 19 20	15 16 17 18 19	14 15 16 17 18	12 14 15 15 16	11 12 13 14 15	10 11 12 13 14	9 10 11 12 13	8 9 10 11 12	7 8 9 10 11	6 7 8 9 10
120 122 124 126 128	29 30 30 31 32	28 28 29 30 30	26 27 28 28 29	25 26 26 27 28	23 24 25 26 26	22 23 24 25 25	21 22 22 23 24	20 21 21 22 22 23	18 19 20 21 22	17 18 19 20 20	16 17 18 19 19	15 16 17 18 18	14 15 16 16 17	13 14 15 15 16	12 13 14 14 15	11 12 13 13 14
130 132 134 136 138	32 33 34 34 35	31 32 32 33 33	30 30 31 32 32	28 29 30 30 31	27 28 28 29 30	26 27 27 28 28	25 25 26 27 27	23 24 25 25 26	22 23 24 24 25	21 22 23 23 24	20 21 21 22 23	19 20 20 21 22	18 19 19 20 21	17 18 18 19 20	16 17 17 18 19	15 16 16 17 18
140	35	34	33	31	30	29	28	27	26	24	23	22	21	20	19	18

The following formula is for 27 in. barometer, or about 3,000 ft. above sea-level (but 1,000 ft. more or less makes little difference) and holds true for all readings likely to occur in the mines.

$$100 - H = (d - w) \left(\frac{165 - d}{20}\right)$$

Thus, if d = 75 and w = 73, $100 - H = 2 \times 4.5$, and H = 91 per cent., and if d = 95 and w = 92, $100 - H = 3 \times 3.5$, H = 89.5 per cent. These both agree very closely with the data in the Smithsonian tables; therefore the formula must be correct for all dry-bulb readings between 75° and 95°F., especially since the wet-bulb cannot be read with sufficient accuracy to give H within $\frac{1}{4}$ per cent.

Table XI.—Pressure of Aqueous Vapor for Temperature from 100° to 445°F., in Inches of Mercury

Temp.,	0	1	2	. 3	4	5	6	7	8	9
100 110 120 130 140	Inches 1.916 2.576 3.425 4.504 5.862	Inches 1.975 2.652 3.522 4.627 •6.015	Inches 2.035 2.730 3.621 4.752 6.171	2.097	2.160	2.975 3.933 5.145	2.292 3.061 4.042		2.431 3.239 4.268	Inches 2.503 3.331 4.385 5.712 7.366
150 160 170 180 190	7.552 9.637 12.187 15.279 19.001	7.742 9.870 12.470 15.621 19.412	7.936 10.108 12.759 15.970 19.830	8.133 10.350 13.054 16.325 20.255		8.541 10.850 13.660 17.055 21.129	13.972	11.369 14.289	9.186 11.636 14.613 18.202 22.499	9.409 11.909 14.943 18.598 22.972
200 210 220 230 240	23.45 28.75 85.01 42.34 50.89	23.94 29.33 35.69 43.14 51.82	24.44 29.92 36.38 43.94 52.76	24.95 30.52 37.08 44.76 53.72	25.46 31.13 37.79 45.59 54.69	25.99 31.75 38.52 46.44 55.67	26.52 32.38 39.26 47.31 56.67	27.06 33.02 40.01 48.19 57.68	27.62 33.67 40.77 49.08 58.71	28.18 34.33 41.55 49.98 59.76
	72.26 85.41 100.41		62.98 74.75 88.25 103.66 121.18		65.20 77.31 91.18 106.99 124.94	66.33 78.61 92.67 108.69 126.86	67.48 79.93 94.18 110.41 128.81	68.66 81.27 95.70 112.15 130.78	69.85 82.63 97.25 113.91 132.78	71.04 84.01 98.82 115.69 134.80
310 320 330	158.7 183.1 210.6	161.0 185.8 213.5	162.3 188.4 216.4	165.7 191.1 219.4	193.8 222.4	170.6 196.5 225.4	173.0 199.3		234.7	156.4 180.5 207.7 237.9 271.5
360 370 380	312.6 354.1 399.7	316.5 358.4 404.5	320.5 362.8 409.3	324.6 367.3 414.1	328.7 371.8	332.8 376.4 424.1	337.0 380.9	341.2 385.5 434.1	345.4 390.2 439.2	308.7 349.7 394.9 444.4 498.7
410 420 430	564.1 628.8 699.2	570.3 6 35.6 706.6	576.6 642.5 714.0	582.9 649.4 721.4	589.3	595.7 663.3	602.3 670.4	608.9	615.5 684.7	557.9 622.1 691.9 767.4

Weight of a Cubic Foot of Aqueous Vapor at Different Temperatures and Saturations (in Grains)

Temp.,				Percer	tage o	f satu	ation			
°F.	10	20	30	40	50	60	70	80	90	100
-20 -19 -18 -17 -16	Gr. 0.017 0.017 0.018 0.020 0.021	Gr. 0.033 0.035 0.037 0.039 0.041	Gr. 0.050 0.052 0.055 0.059 0.062	0.070 0.074		Gr. 0.100 0.104 0.100 0.118 0.124	0.122 0.129	Gr. 0.133 0.139 0.147 0.157 0.166	0.166	Gr. 0.166 0.174 0.184 0.196 0.207
-15 -14 -13 -12 -11	0.022 0.023 0.024 0.026 0.027	0.044 0.046 0.049 0.051 0.054	0.073 0.077 0.081	0.097 0.103 0.108	0.109 0.116 0.122 0.128 0.135	0.139 0.146 0.154 0.162	0.170 0.180 0.189	0.194 0.206 0.216	0.208 0.219	0.218 0.231 0.243 0.257 0.270
—10 — 9 — 8 — 7 — 6	0.028 0.030 0.032 0.033 0.035	0.057 0.060 0.063 0.066 0.070	0.095	0.120 0.126	0.150	0.180 0.190 0.199	0.221	0.228 0.240 0.253 0.266 0.280	0.256 0.270 0.284 0.299 0.315	0.285 0.300 0.316 0.332 0.350
- 5 - 4 - 3 2	0.037 0.039 0.041 0.043 0.046	0.074 0.078 0.082 0.087 0.091		0.164			0.259 0.272 0.288 0.304 0.320	0.296 0.311 0.329 0.347 0.366	0.333 0.350 0.370 0.391 0.411	0.370 0.389 0.411 0.434 0.457
0 1 2 3 4	0.048 0.050 0.053 0.055 0.058	0.096 0.101 0.106 0.111 0.116	0.152 0.159 0.166	0.192 0.202 0.212 0.222 0.233	0.240 0.252 0.264 0.277 0.291	0.303	0.354 0.370 0.388	0.385 0.404 0.423 0.443 0.466	0.476	0.481 0.505 0.529 0.554 0.582
5 6 7 8 9	0.061 0.064 0.067 0.070 0.074		0.192 0.201 0.211	0.244 0.256 0.268 0.282 0.296		0.383 0.403	0.447 0.470	0.488 0.511 0.537 0.563 0.591		0.610 0.639 0.671 0.704 0.739
10 11 12 13 14	0.078 0.082 0.086 0.090 0.094	0.155 0.163 0.171 0.180 0.188		0.310 0.326 0.342 0.359 0.376	0.388 0.408 0.428 0.449 0.470	0.490 0.514	0.543 0.571 0.599 0.629 0.659	0.621 0.653 0.685 0.718 0.753	0.698 0.734 0.770 0.808 0.847	0.776 0.816 0.856 0.898 0.941
15 16 17 18 19	0.099 0.103 0.108 0.113 0.118	0.206 0.216 0.226	0.310 0.324	0.394 0.413 0.432 0.451 0.472	0.493 0.516 0.540 0.564 0.590	0.619 0.648 0.677	0.690 0.722 0.756 0.790 0.827	0.789 0.826 0.864 0.902 0.845	0.887 0.929 0.972 1.015 1.063	0.986 1.032 1.080 1.128 1.181
20 21 22 23 24	0.124 0.129 0.136 0.142 0.148		0.370 0.388 0.406 0.425 0.445		0.618 0.647 0.678 0.709 0.742	0.741 0.776 0.813 0.851 0.890	0.864 0.906 0.948 0.993 1.038	0.988 1.035 1.084 1.134 1.186	1.112 1.165 1.220 1.276 1.335	1.235 1.294 1.355 1.418 1.483
25 26 27	0.155 0.162 0.170	0.310 0.325 0.339	0.465 0.487 0.509	0.649	0.776 0.812 0.848		1.086 1.136 1.188	1.241 1.298 1.358	1.396 1.461 1.527	1.551 1.623 1.697

WEIGHT OF A CUBIC FOOT OF AQUEOUS VAPOR AT DIFFERENT TEMPERATURES AND SATURATIONS (IN GRAINS). Continued

Temp.,	Percentage of saturation									
°F.	10	20	30	40	50	60	70	80	90	100
28 29	Gr. 0.177 0.185	Gr. 0.355 0.371	Gr. 0.532 0.556	Gr. 0.709 0.741	Gr. 0.886 0.926			Gr. 1.418 1.482		Gr. 1.773 1.853
30 31 32 33 34	0.194 0.202 0.211 0.219 0.228	0.387 0.404 0.422 0.439 0.456		0.809 0.845		1.213 1.268 1.316	1.415 1.479 1.536	1.618 1.690 1.755	1.820 1.902 1.975	2.113
35 36 37 38 39	0.237 0.246 0.255 0.265 0.275	0.473 0.491 0.510	0.710 0.737 0.765 0.794	0.946 0.983 1.020 1.058	1.183 1.228 1.275 1.323	1.420 1.474 1.530 1.588	1.656 1.720 1.785 1.852	1.893 1.966 2.040 2.117	2.129 2.211 2.295 2.381	2.366 2.457 2.550
40 41 42 43 44	0.285 0.296 0.306 0.318 0.329	0.570 0.591 0.613 0.635	0.855 0.886 0.919 0.953	1.140 1.182 1.226 1.271	1.424 1.478 1.532 1.588	1.709 1.773 1.838 1.906	1.994 2.068 2.145 2.224	2.279 2.364 2.451 2.542	2.564 2.660 2.758 2.859	2.849 2.955 3.064 3.177
45 46 47 48 49	0.341 0.354 0.367 0.380 0.394	0.683 0.708 0.733 0.760	1.024 1.062 1.100 1.140	1.366 1.416 1.467	1.707 1.770 1.834 1.900	2.048 2.123 2.200 2.280	2.390 2.477 2.567 2.660	2.731 2.831 2.934 3.040	3.073 3.185 3.300 3.420	3.414 3.539 3.667 3.800
50 51 52 53 54	0.408 0.422 0.437	0.815 0.844 0.874 0.907	1.223 1.267 1.312 1.358	1.630 1.689 1.749 1.810	2.038 2.111 2.186 2.263	2.446 2.533 2.623 2.716	2.853 2.955 3.060 3.168	3.261 3.378 3.498 3,621	3.668 3.800 3.935 4.073	4.076 4.222 4.372 4.526
55. 56 57 58 59	0.485 0.502 0.519 0.537 0.556	1.003 1.038 1.074	1.505 1.557	2.006 2.076 2.148	2.508 2.596	3.010 3.115 3.222	3.511 3.634 3.759	4.013 4.153 4.296	3.514 4.672 4.833	
60 61 62 63 64	0.574 0.594 0.614 0.635 0.656	1.188 1.228 1.270	1.782 1.843 1.905	2.457	2.970 3.071	3.565 3.685 3.809	4.159 4.299 4.44	4.753 4.914 5.079	5.347 5.528 5.714	5.941 6.142
65 66 67 68 69	0.678 0.701 0.724 0.748 0.773	1.356 1.402 1.448 1.496 1.545	2.103 2.172 2.244		3.504 3.620	4.205 4.345	4.906 5.069	5.607 5.793 5.984	6.308 6.517	
70 71 72 73 74	0.798 0.824 0.851 0.878 0.907	1.702 1.756	2.472 2.552 2.635	3.403 3.513	4.120 4.254 4.391	4.944 5.105 5.269	5.768 5.956 6.147	6.592 6.806 7.026	7.416 7.657 7.904	8.240 8.508 8.782

WEIGHT OF A CUBIC FOOT OF AQUEOUS VAPOR AT DIFFERENT TEMPERATURES AND SATURATIONS (IN GRAINS). Continued

Temp.,	Percentage of saturation									
•F.	10	20	30	40	50	60	70	80	90	100
	Gr.	Gr.	Gr.	Gr.	Gr.	Gr.	Gr.	Gr.	Gr.	Gr.
75	0.936	1.871	2.807	3.742	4.678			7.485	8.420	
76	0.966	1.931	2.896	3.862					8.690	
77 78	0.996 1.028	1.992 2.055	2.989 3.083	3.985 4.111					8.966	9.962 10.277
79	1.060		3.180					8.481		10.601
80	1.093	2.187							9.841	10.934
81	1.128	2.255							10.148	
82	1.163	2.325							10.463	
83 84	1.199 1.236	2.397 2.471	3.596 3.707	4.795 4.942					10.788 11.120	
85	1.274	2.547	3.821	5.094	6.368			10.189		
86	1.313	2.625			6.564			10.502		
87	1.353	2.705					9.468			
88	1.394	2.787	4.181	5.575			9.756			
89	1.436	2.872	4.308	5.744	7.180	8.615	10.051	11.487	12.923	14.359
90	1.479						10.353			
91	1.523	3.047					10.664			
92	1.569						10.982			
93 94	1.616 1.663	3.231 3.327	4.846 4.990				11.308 11.644			
• 95	1.712	3.425	5.137	6.850	8.562	10.274	11.987	13.699	15:412	17.124
96	1.763	3.525	5.288	7.050	8.813	10.576	12.338	14.101	15.863	17.626
97	1.814						12.699			
98	1.867			7.468			13.070			
99	1.921	3.842	5.764	7.685	9.606	11.527	13. 44 8	15.370	17.291	19.212
100	1.977	3.952					13.836			
101	2.034	4.067	6.100				14.234			
102	2.092						14.642			
103	2.151						15.060			
104	2.212	4.425	6.638	8.850	11.062	13.275	15.488	17.700	19.912	22.125
105	2.275						15.925			
106	2.339	4.678	7.018	9.357	11.696	14.035	16.374	18.714	21.053	23.392
107	2.405						16.834			
108	2.472		7.416	9.888	12.360	14.832	17.304	19.776	22.248	24.720
109	2.541	5.082	7.622	10.163	12.704	15.245	17.786	20.326	22.867	25.408
110	2.611	5.222	7.834	10.445	13.056	15.667	18.278	20.890	23.501	26.112

TENSION OF AQUEOUS VAPOR AT VARIOUS TEMPERATURES¹

Temperature, degrees C.	Tension of aqueous vapor in mm.	Temperature, degrees C.	Tension of aque- ous vapor in mm
0	4.525	21 .	18.505
	4.867	22	19.675
1 2 3 4	5.231	23	20.909
3	5.619	24	22.211
4	6.032	25	23.582
5	6.471	26	25.026
	6.939	27	26.547
6 7 8 9	7.436	28	28.148
8	7.964	29	29.832
9	8.525	. 30	31.602
10	9.126	31	33.464
11	9.751	32	35.419
12	10.421	33	37.473
13	11.130	34	39.630
14	11.882	35	41.893
15	12.677	36	44.268
16	13.519	37	46.758
17	14.409	38	49.368
18	15.351	39	52.103
19	16.345	40	54.969
20	17.396		

¹ WINKLER, "Technical Gas Analysis."

BAROMETRIC CORRECTIONS

CORRECTIONS FOR TEMPERATURE (Mercury, brass scale correct at 0°C.)

Tommonaturo	Millimeters											
Temperature	73	74	75	76	77	78	79					
15°	0.178	0.181	0.183	0.186	0.188	0.191	0.193					
16	0.190	0.193	0.196	l i			0.206					
17	0.202	0.205	0.208	0.210	0.213	0.216	0.218					
18	0.214	0.217	0.220	0.223	0.226	0.229	0.231					
19	0.226	0.229	0.232	0.235	0.238	0.241	0.244					
20	0.238	0.241	0.244	0.247	0.251	0.254	0.257					
21	0.250	0.253	0.256	0.260	0.263	0.267	0.270					
22	0.261	0.265	0.269	0.272	0.276	0.279	0.283					
23	0.273	0.277	0.281	0.284	0.288	0.292	0.296					
24	0.289	0.289	0.293	0.297	0.301	0.305	0.309					

Corrections must be subtracted from observed readings, if reading at 19°C. is 76 cm., the corrected reading is 76 - 0.235.

EFFECT OF ALTITUDE¹

Table of altitudes in feet above sea-level; with corresponding approximate barometric readings, atmospheric pressures and proportionate densities. (The capacity of an internal combustion engine at higher altitudes, as compared with its capacity at sea-level, is practically proportional to the atmospheric densities.)

Altitude in feet	Barometer in inches	Atmospheric pressure in pounds per square inch	Proportionate atmospheric density
0.00	30.0	14.72	1.00
500.0	29.5	14.45	0.98
1,000.0	28.9	14.18	0.96
1,500.0	28.4	13.94	0.94
2,000.0	27.9	13.69	0.93
2,500.0	27.4	13.45	0.91
3,000.0	26.9	13.20	0.89
4,000.0	26.0	12.75	0.86
5,000.0	25.1	12.30	0.83
6,000.0	24.2	11.85	0.80
7,000.0	23.3	11.44	0.77
8,000.0	22.5	11.04	0.75
9,000.0	$\frac{1}{21.7}$	10.65	0.73
10,000.0	20.9	10.26	0.70

¹ From the "Diesel Engine," Busch-Sulzer Bros. Diesel Engine Co.

CORRECTION TO BE ADDED FOR CAPILLARITY

Diameter	Height of meniscus in inches											
tube in inches	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08				
0.15	0.024	0.047	0.069	0.092	0.116							
0.20	0.011	0.022	0.033	0.045	0.059	0.079						
0.25	0.006	0.012	0.019	0.028	0.037	0.047	0.059					
0.30	0.004	0.008	0.013	0.018	0.023	0.029	0.035	0.042				
0.35		0.005	0.008	0.012	0.015	0.019	0.022	0.027				
0.40		0.004	0.006	0.008	0.010	0.012	0.014	0.016				
0.45			0.003	0.005	0.007	0.008	0.010	0.012				
0.50			0.002	l .	1	0.006	•					
0.55			0.001	1		0.004						

From Ellenwood's "Steam Charts," abbr. from Smithsonian table No. 103.

Barometer Correction for Variation in g—Correct at 45° N. or S. Latitude

	73	74	75	·76	77	78	79
35° or 55°	0.065	0.066	0.066	0.067	0.068	0.069	0.07 0
40° or 50°	0.032	0.033	0.033	0.034	0.035	0.035	0.03 5

Subtract the correction for 35° and 40°. Add the correction for 50° and 55°.

BATTERIES, E.M.F. OF STANDARD CELLS

Cell	Description	E.m.f.	Resist- ance
Bichromate .	Zn and C in 1 vol. strong H ₂ SO ₄ and 20 vol. sat. K ₂ Cr ₂ O ₇ sol.	2.0	Very low
Bunsen	Zn in 1 vol. strong H ₂ SO ₄ : 12 vol. H ₂ O C in strong HNO ₂ .	1.8-1.9	
Clark	Zn amalgam and Hg in sat. ZnSO ₄ sol.	1.433	About 500
Daniell	Zn in ZnSO ₄ sol, or H ₂ SO ₄ (1:12) Cu in sat. CuSO ₄ sol.	1.07-1.08	About 4
Grove	Like Bunsen, C replaced by Pt.	1.8-1.9	
Leclanché		1.5	0.25-0.4
Secondary		2.2-1.9	
Tucker		1.4	
Weston	Cd amalgam. and Hg in sat. CdSO ₄ sol.	1.018	About 500
Edison	CuO and Zn in NaOH.	1.12	0.02-0.09

HYDROMETER CONVERSION FACTORS

Liquids lighter than water
$$\begin{cases} \frac{140}{\text{Bé.}^{\circ} + 130} = \text{sp. gr.} & \text{Liquids heavier} \\ \frac{140}{\text{sp. gr.}} - 130 = \text{Bé.}^{\circ} & \text{than water} \end{cases} \text{Sp. gr.} = \frac{145}{145 - \text{Bé.}^{\circ}}$$

$$\begin{cases} \text{Bé.}^{\circ} = 145 - \frac{145}{\text{sp. gr.}} \end{cases}$$

To correct Bé, readings to 60°: Correct reading = observed reading + $\frac{60 - t}{10}$

For the Twaddell hydrometer:

$$\frac{\text{Tw.}^{\circ}}{200} + 1 = \text{sp. gr.}$$

200(sp. gr. - 1) = Tw.°

For the Gay-Lussac (standardized at 4°C.):

$$\frac{100}{\text{G.-L.}^{\circ} + 100} = \text{sp. gr.}$$

$$\frac{100}{\text{sp. gr.}} - 100 = \text{G.-L.}^{\circ}$$

For the Sikes hydrometer: 1° = 0.002 of sp. gr.

For the Beck (12.5°C.); sp. gr. =
$$\frac{170}{170 + \text{Beck}^{\circ}}$$

For the Cartier (12.5°): sp. gr. =
$$\frac{136}{126.1 + \text{Cart.}^{\circ}}$$

For the Brix and the Fisher (15.6°C.): sp. gr. =
$$\frac{400}{400 + n^6}$$

Conversion Table for Degrees Baumé¹ (Liquids lighter than water²)

<u> </u>	·	Didding nighte	TOTAL WALC	<u> </u>	,
Degrees Baumé	Sp. gr.	Pounds in 1 gal. American ²	Degrees Baumé	Sp. gr.	Pounds in 1 gal. American ²
10	1.0000	8.33	43	0.8092	6.74
11	0.9929	8.27	44	0.8045	6.70
$\overline{12}$	0.9859	8.21	45	0.8000	6.66
13	0.9790	8.16	46	0.7954	6.63
14	0.9722	8.10	47	0.7909	6.59
15	0.9655	8.04	48	0.7865	6.55
16	0.9589	7.99	49	0.7821	6.52
17	0.9523	7.93	50	0.7777	6.48
18	0.9459	7.88	51	0.7734	6.44
19	0.9395	7.83	52	0.7692	6.41
· 20	0.9333	7.78	53	0.7650	6.37
21	0.9271	7.72	54	0.7608	6.34
22	0.9210	7.67	5 5	0.7567	6.30
23	0.9150	7.62	56	0.7526	6.27
24	0.9090	7.57	57	0.7486	6.24
25	0.9032	7.53	58	0.7446	6.20
26	0.8974	7.48	59	0.7407	6.17
27	0.8917	7.43	60	0.7368	6.14
28	0.8860	7.38	61	0.7329	6.11
29	0.8805	7.34	62	0.7290	6.07
. 30	0.8750	7.29	63	0.7253	. 6.04
31	0.8695	7.24	64	0.7216	6.01
32 -	0.8641	7.20	65	0.7179	5.98
33	0.8588	7.15	66	0.7142	5.95
34	0.8536	7.11	67	0.7106	5.92
35	0.8484	7.07	68	0.7070	5.89
36	0.8433	7.03	69	0.7035	5.86
37	0.8383	6.98	70	0.7000	5.83
38	0.8333	6.94	71	0.6829	5.69
39	0.8284	6.90	72	0.6666	5.55
40	0.8235	6.86	73 .	0.6511	5.42
41	0.8187	6.82	74	0.6363	5.30
42	0.8139	6.78	75	0.6222	5.18
	1		<u> </u>	 	<u> </u>

The Baumé scale is entirely arbitrary, so various authorities give various values for the above table. These given above are from a table specially calculated for the "Petroleum Year Book, 1914" by TAGLIABUE of New York. The formulas on p. 112 were also furnished by him for the same work.

For liquids heavier than water, see the sulphuric acid table on page 115.

Sp. gr. × 10 = pounds per imperial gallon.

Specific Gravity of Sulphuric Acid¹ at 15°C., Compared to Water at 4°C.

		,,,,,,,	THE MAL T			
Sp. gr. at.	Degrees	Degrees	100 part	s of c.p. ac	id contain	, per cent.
40	Kouma l'Impaddall		SO ₈	H ₂ SO ₄	60°Bé. acid	50°Bé. acid
1.000	$egin{array}{c} 0.0 \\ 0.7 \\ 1.4 \\ 2.1 \\ 2.7 \\ 3.4 \\ \end{array}$	0	0.07	0.09	0.12	0.14
1.005		1	0.68	0.83	1.06	1.33
1.010		2	1.28	1.57	2.01	2.51
1.015		3	1.88	2.30	2.95	3.68
1.020		4	2.47	3.03	3.88	4.85
1.025		5	3.07	3.76	4.82	6.02
1.030 1.035 1.040 1.045 1.050	4.1 4.7 5.4 6.0 6.7	6 7 8 9	3.67 4.27 4.87 5.45 6.02	4.49 5.23 5.96 6.67 7.37	5.78 6.73 7.64 8.55 9.44	7.18 8.37 9.54 10.67 11.79
1.055	7.4	11	6.59	8.07	10.34	12.91
1.060	8.0	12	7.16	8.77	11.24	14.03
1.065	8.7	13	7.73	9.47	12.14	15.15
1.070	9.4	14	8.32	10.19	13.05	16.30
1.075	10.0	15	8.90	10.90	13.96	17.44
1.080	10.6	16	9.47	11.60	14.87	18.56
1.085	11.2	17	10.04	12.30	15.76	19.68
1.090	11.9	18	10.60	12.99	16.65	20.78
1.095	12.4	19	11.16	13.67	17.52	21.87
1.100	13.0	20	11.71	14.35	18.39	22.96
1.105	13.6	21	12.27	15.03	19.26	24.05
1.110	14.2	22	12.82	15.71	20.13	25.14
1.115	14.9	23	13.36	16.36	20.96	26.18
1.120	15.4	24	13.89	17.01	21.80	27.22
1.125	16.0	25	14.42	17.66	22.63	28.26
1.130	16.5	26	14.95	18.31	23.47	29.30
1.135	17.1	27	15.48	18.96	24.29	30.34
1.140	17.7	28	16.01	19.61	25.13	31.38
1.145	18.3	29	16.54	20.26	25.96	32.42
1.150	18.8	30	17.07	20.91	26.79	33.46
1.155	19.3	31	17.59	21.55	27.61	34.48
1.160	19.8	32	18.11	22.19	28.43	35.50
1.165	20.3	33	18.64	22.83	29.35	36.53
1.170	20.9	34	19.16	23.47	30.07	37.55
1.175	21.4	35	19.69	24.12	30.90	38.59

SPECIFIC GRAVITY OF SULPHURIC ACID¹ AT 15°C., COMPARED TO WATER AT 4°C. Continued

Sp. gr. at	Degrees	Degrees	100 parts of c.p. acid contain, per cent.				
15° 4°	Dayma True		SO:	H2SO4	60°Bé. acid	50°Bé. acid	
1.180	22.0	36	20.21	24.76	31.73	39.62	
1.185	22.5	37	20.73	25.40	32.55	40.64	
1.190	23.0	38	21.26	26.04	33.37	41.66	
1.195	23.5	39	21.78	26.68	34.19	42 .69	
1.200	24.0	40	22.30	27.32	35.01	43.71	
1.205	24.5	41	22.82	27.95	35.83	44.72	
1.210	25 .0	42	23.33	28.58	36.66	45.73	
1.215	25.5	43	23.84	29.21	37.45	46.74	
1.220	26.0	44	24.36	29.84	38.23	47.74	
1.225	26.4	45	24.88	30.48	39.05	48.77	
1.230	26.9	46	25.39	31.11	39.86	49.78	
1.235	27 . 4	47	25 .88	31.70	40.61	50.72	
1.240	27 .9	48	26 .35	32.28	41.37	51.65	
1.245	28.4	49	26.83	32.86	42.11	52.58	
1.250	28.8	50	27.29	33.43	42.84	53.49	
1.255	29.3	51	27.76	34.00	43.57	54.40	
1.260	29.7	52	28.22	34.57	44.30	55.31	
1.265	30.2	53	28.69	35.14	45.03	56.22	
1.270	30.6	54	29.15	35.71	45.76	57.14	
1.275	31.1	55	29.62	36.29	46.50	58.06	
1.280	31.5	56	30.10	36.87	47.24	58.99	
1.285	32 .0	57	30.57	37.45	47.99	59.92	
1.290	32.4	58	31.04	38.03	48.73	60.85	
1.295	32.8	59	31.52	38.61	49.47	61.78	
1.300	33.3	60	31.99	39.19	50.21	62.70	
1.305	33.7	61	32.46	39.77	50.96	63.63	
1.310	34 .2	62	32.94	40.35	51.71	64.56	
1.315	34.6	63	33.41	40.93	52.45	65.45	
1.320	35.0	64	33.88	41.50	53.18	66.40	
1.325	• 35.4	65	34.35	42.08	53.92	67.33	
1.330	35.8	66	34.80	42.66	54.67	68.26	
1.335	36.2	67	35.27	43.20	55.36	69.12	
1.340	36 .6	68	35.71	43.74	56.05	69.98	
1.345	37.0	69	36.14	44.28	56.74	70.85	
1.350	37.4	70	36.58	44.82	57.43	71.71	
1.355	37.8	71	37.02	45.35	58.11	72.56	

Specific Gravity of Sulphuric Acid¹ at 15°C., Compared to Water at 4°C. Continued

		AIER AI	1 0. 00	in the contraction of the contra			
Sp. gr. at	Degrees	Degrees	100 parts of c.p. acid contain, per cent.				
4°	Baumé	Twaddell	SO:	H ₂ SO ₄	60°Bé. acid	50°Bé.	
1.360	38.2	72	37.45	45.88	58.79	73.41	
1.365	38.6	73	37.89	46.41	59.48	74.26	
1.370	39.0	74	38.32	46.94	60.15	75.10	
1.375	39.4	75	38.75	47.47	60.83	75.95	
1.380	39.8	76	39.18	48.00	61.51	76.80	
1.385	40.1	77	39.62	48.53	62.19	77.65	
1.390	40.5	78	40.05	49.06	62.87	78.50	
1.395	40.8	79	40.48	49.59	63.55	79.34	
1.400	41.2	80	40.91	50.11	64.21	80.18	
1.405	41.6	81	41.33	50.63	64.88	81,01	
1.410	42.0	82	41.76	51.15	65.55	81.86	
1.415	42.3	83	42.17	51.66	66.21	82.66	
1:420	42.7	84	42.57	52.15	66.82	83.44	
1.425	43.1	85	42.96	52.63	67.44	84.21	
1.430	43.4	86	43.36	53.11	68.06	84.98	
1.435	43.8	87	43.75	53.59	68.68	85.74	
1.440	44.1	88	44.14	54.07	69.29	86.51	
1.445	44.4	89	44.53	54.55	69.90	87.28	
1.450	44.8	90	44.92	55.03	70.52	88.05	
1.455	45.1	91	45.31	55.50	71.12	88.80	
1.460	45.4	92	45.69	5 5.97	71.72	89.5 5	
1.465	45.8	93	46.07	56.43	72.31	90.29	
1.470	46.1	94	46.45	56 .90	72.91	91.04	
1.475	46.4	95	46.83	57.37	73.51	91.79	
1.480	46.8	96	47.21	57.83	74.10	92.53	
1.485	47.1	97	47.57	58 .28	74:68	93.25	
1.490	47.4	98	47.95	58.74	75.27	93.98	
1.495	47.8	99	48.34	59.22	75.88	94.75	
1.500	48.1	100	48.73	59.70	76.50	95 .52	
1.505	48.4	101	49.12	60.18	77.12	96.29	
1.510	48.7	102	49.51	60.65	77.72	97.04	
1.515	49.0	103	49.89	61.12	78.32	97.79	
1.520	49.4	104	50.28	61.59	78.93	98.54	
1.525	49.7	105	50.66	62.06	79.52	99.30	
1.530	50.0	106	51.04	62 .53	80.13	100.05	
ı	•	. · · · · · · · · · · · · · · · · · · ·					

Specific Gravity of Sulphuric Acid¹ at 15°C., Compared to Water at 4°C. Continued

		,	100 parts of c.p. acid contain, per cent.				
Sp. gr. at	Degrees	Degrees	100 parts	or c.p. acid	i contain,	per cent.	
40	Baumé	Twaddell	SO ₂	H ₂ SO ₄	60°Bé. acid	50°Bé. acid	
1.535	50.3	107	51.43	63.00	80.73	100.80	
1.540	50.6	108	51.78	63.43	81.28	101.49	
1.545	50.9	109	52.12	63.85	81.81	102.16	
1.550	51:2	110	52.46	64.26	82.34	102.82	
1.555	51.5	111	52.79	64.67	82.87	103.47	
1.560	51.8	112	53.12	65.08	83.39	104.13	
1.565	52.1	113	53.46	65.49	83.92	104.78	
1.570	52.4	114 115	53.80	65.90	84.44	105.44	
1.575	52.7	110	54.13	66.30	84.95	106.08	
1.580	53.0	116	54.46	66.71	85.48	106.73	
1.585	53.3	117.	54.80	67.13	86.03	107.41	
$\begin{array}{c} \textbf{1.590} \\ \textbf{1.595} \end{array}$	53.6 53.9	118 119	55.18 55.55	67.59 68.05	86.62 87.20	108.14 108.88	
1.600	54.1	120	55.93	68.51	87.79	109.62	
1.605	54.4	121	56.30	68.97	88.38	110.35	
1.610 1.615	54.7 55.0	122 123	56.68 57.05	69.43 69.89	88.97 89.56	111.09 111.82	
1.620	55.2	124	57.40	70.32	90.11	112.51	
1.625	55.5	125	57.75	70.74	90.65	113.18	
1.630	55.8	126	58.09	71.16	91.19	113.86	
1.635	56.0	127	58.43	71.57	91.71	I	
1.640	56.3	128	58.77	71.99	92.25	1	
1.645	56.6	129	59.10	72.40			
1.650	56.9	130	59.45	72.82	93.29	116.51	
1.655	57.1	131	59.78	73.23	93.81	117.17	
1.660	57.4	132	60.11	73.64	94.36	1	
1.665	57.7	133	60.46	74.07	94.92	1	
$egin{array}{c} 1.670 \ 1.675 \end{array}$	57.9 58.2	134 135	60.82	74.51 74.97	95.48	119. 22 119.95	
1.070	00.2	100	01.20	14.51	90.07	119.90	
1.680	58.4	136	61.57	75.42	96.65		
1.685	58.7	137	61.93	75.86	97.21	121.38	
1.690 1.695	58.9 59.2	138 139	62.29	76.30 76.73	97.77	122.08 122.77	
1.700	59.5	140	63.00	77.17	98.89	123.47	
	1						
1.705	59.7	141	63.35	77.60	99.44		
1.710	60.0	142	63.70	78.04	100.00	124.86	

Specific Gravity of Sulphuric Acid¹ at 15°C., Compared to Water at 4°C. Continued

	, vv	ATER AT	t C. Co	nunuea_			
Sp. gr. at 15°	Degrees	Degrees	100 parts	s of c.p. ac	p. acid contain, per cent.		
40	/ Danas / Wassadala		808	H ₂ SO ₄	60°Bé. acid	50°Bé. acid	
1.715	60.2	143	64.07	78.48	100.56	125.57	
1.720	60.4	144	64.43	78.92	101.13	126.27	
1.725	60.6	145	64.78	79.36	101.69	126.98	
1.730	60.9	146	65.14	79.80	102.25	127.68	
1.735	61.1	147	65.50	80.24	102.82	128.38	
1.740	61.4	148	65.86	80.68	103.38	129.09	
1.745	61.6	149	66.22	81.12	103.95	129.79	
1.750	61.8	150	66.58	81.56	104.52	130.49	
1.755	62.1	151	66.94	82.00	105.08	131.20	
1.760	62.3	152	67.30	82.44	105.64	131.90	
1.765	62.5	153	67.65	82.88	106.21	132.61	
1.770	62.8	154	68.02	83.32	106.77	133.31	
1.775	63.0	155	68.49	83.90	107.51	134.24	
1.780	63.2	156	68.98	84.50	108.27	135.20	
1.785	63.5	157	69.47	85.10	109.05	136.16	
1.790	63.7	158	69.96	85.70	109.82	137.14	
1.795	64.0	159	70.45	86.30	110.58	138.08	
1.800	64.2	160	70.94	86.90	111.35	139.06	
1.805	64.4	161	71.50	87.60	112.25	140.16	
1.810	64 .6	162	72.08	88.30	113.15	141.28	
1.815	64.8	163	72.69	89.05	1	142.48	
1.820	65.0	, 16 4	73.51		115.33		
1.821	• • • • • • • •		73.63	90.20	115.59	144.32	
1.822	65.1		73.80		115.84		
1.823	•••••	• • • • • • • • •	73.96		116.10		
1.824	65.2		74.12			145.28	
1.825	•••••	165	74.29			145.60	
1.826	65.3		74.49	91.25	116.93	146.00	
1.827			74.69			146.40	
1.828		• • • • • • •	74.86			146.72	
1.829	• • • • • • • • •		75.03			147.04	
1.830	QE F	166	75.19			147.36	
1.831	65.5		75.35	92.30	118.27	147.68	
1.832		*	75.53	92.52	118.56	148.03	
1.833	65.6		75.72	92.75	118.85	148.40	
<u>. </u>				· · · · · · · · · · · · · · · · · · ·		 	

SPECIFIC GRAVITY OF SULPHURIC ACID¹ AT 15°C., COMPARED TO WATER AT 4°C. Continued

Sp. gr. at	Degrees	Degrees	100 parts of c.p. acid contain, per cent.				
40	Down	Twaddell	80:	H ₂ SO ₄	60°Bé. acid	50°Bé. acid	
1.834 1.835 1.836	65.7	167	75.96 76.27 76.57	93.05 93.43 93.80	119.23 119.72 120.19	148.88 149.49 150.08	
1.837 1.838 1.839 1.840 1.8405	65.8 65.9	168	76.90 77.23 77.55 78.04 78.33	94.20 94.60 95.00 95.60 95.95	120.71 121.22 121.74 122.51 122.96	150.72 151.36 152.00 152.96 153.52	
1.8410 1.8415 1.8410 1.8405 1.8400			79.19 79.76 80.16 80.57 80.98	97.00 97.70 98.20 98.70 99.20	124.30 125.20 125.84 126.48 127.12	155.20 156.32 157.12 157.92 158.72	
1.8395 1.8390 1.8385	• • • • • • • • •	•••••	81.18 81.39 81.59	99.45 99.70 99.95	127.44 127.76 128.08	159.12 159.52 159.92	

According to Lunge and Isler, and Lunge and Nasy. Lunge, "The Manufacture of Sulphuric Acid and Alkali," D. Van Nostrand & Co., New York.

To reduce specific gravities observed at other temperatures than 15°C. to 15°C., roughly: For each degree above or below 15°, add to or subtract from the specific gravity observed:

- 0.0006 with acids to 1.170
- 0.0007 with acids from 1.170 to 1.450
- 0.0008 with acids from 1.450 to 1.580
- 0.0009 with acids from 1.580 to 1.750
- 0.0010 with acids from 1.750 to 1.840

		Per cent. 66° acid			Melts at	Sp. gr.
66° acid	= 93.19 =	100.00 =	119.98	538°F.	-29°F.	1.8354
60° acid	= 77.67 =	83.35 =	100.00	386°F.	+12°F.	1.7059
50° acid	= 62.18 =	88 72 =	80 0A	295°F	-27°F	1 5263

Note.—The table given on pp. 114 to 119 is used by the dye-makers, that on pp. 120 and 121 by the acid manufacturers and powder plants. The differences are in the third or fourth figures and are probably less than the errors of observation. The New Jersey Zinc Co. uses figures differing slightly from both tables.

SPECIFIC GRAVITY OF SULPHURIC ACID AT 60°F., COMPARED WITH WATER AT 60°F.

This table is the one approved and adopted as a standard by the Manufacturing Chemists Association of the United States. (See note on p. 119.)

facturing	Chemists A	Association	of the Uni	ted States.	(See no	te on p. 119.)
Degrees Baumé	Sp. gr. at 60°	Degrees Twaddell	Wt. of 1 cu. ft. in lb. Avoir.	Per cent. H ₂ SO ₄	Lb. of 66° acid in 1 cu. ft.	Melting (or freezing) point, °F.
0	1.0000	0.0	62.37	0.00	0.00	32.0
1	1.0069	1.4	62.80	1.02	0.68	31.2
2	1.0140	2.8	63.24	2.08	1.41	30.5
3	1.0211	4.2	63.69	3.13	2.14	29.8
4	1.0284	5.7	64.14	4.21	2.90	28.9
5	1.0357	7.1	64.60	5.28	3.66	28.1
6 7 8 9	1.0432 1.0507 1.0584 1.0662 1.0741	8.6 10.1 11.7 13.2 14.8	65.06 65.53 66.01 66.50 66.99	6.37 7.45 8.55 9.66 10.77	4.45 5.24 6.06 6.89 7.74	27.2 26.3 25.1 24.0 22.8
11	1.0821	16.4	67.49	11.89	8.61	21.5
12	1.0902	18.0	68.00	13.01	9.49	20.0
13	1.0985	19.7	68.51	14.13	10.39	18.3
14	1.1069	21.4	69.04	15.25	11.30	16.6
15	1.1154	23.1	69.57	16.38	12.23	14.7
16	1.1240	24.8	70.10	17.53	13.19	12.6 10.2 7.7 4.8 $+1.6$
17	1.1328	26.6	70.65	18.71	14.18	
18	1.1417	28.3	71.21	19.89	15.20	
19	1.1508	30.2	71.78	21.07	16.23	
20	1.1600	32.0	72.35	22.25	17.27	
21	1.1694	33.9	72.94	23.43	18.34	$ \begin{array}{r} -1.8 \\ -6.0 \\ -11.0 \\ -16.0 \\ -23.0 \end{array} $
22	1.1789	35.8	73.53	24.61	19.42	
23	1.1885	37.7	74.13	25.81	20.53	
24	1.1983	39.7	74.74	27.03	21.68	
25	1.2083	41.7	75.36	28.28	22.87	
26	1.2185	43.7	76.00	29.53	24.08	$ \begin{array}{r} -30.0 \\ -39.0 \\ -49.0 \\ -61.0 \\ -74.0 \end{array} $
27	1.2288	45.8	76.64	30.79	25.32	
28	1.2393	47.9	77.30	32.05	26.58	
29	1.2500	50.0	77.96	33.33	27.88	
30	1.2609	52.2	78.64	34.63	29.22	
31	1.2719	54.4	79.33	35.93	30.58	-82.0 -96.0 -97.0 -91.0 -81.0
32	1.2832	56.6	80.03	37.26	32.00	
33	1.2946	58.9	80.74	38.58	33.42	
34	1.3063	61.3	81.47	39.92	34.90	
35	1.3182	63.6	82.22	41.27	36.41	
36	1.3303	66.1	82.97	42.63	37.95	-70.0 -60.0 -53.0 -47.0 -41.0
37	1.3426	68.5	83.74	43.99	39.53	
38	1.3551	71.0	84.52	45.35	41.13	
39	1.3679	73.6	85.32	46.72	42.77	
40	1.3810	76.2	86.13	48.10	44.45	

SPECIFIC GRAVITY OF SULPHURIC ACID AT 60°F., COMPARED WITH WATER AT 60°F.

WITH WATER AT 60°F.

This table is the one approved and adopted as a standard by the Manufacturing Chemists Association of the United States. (See note on p. 119.)

Degrees Baumé	Sp. gr. at 60°	Degrees Twaddell	Wt. of 1 cu. ft. in lb. Avoir.	Per cent. H ₂ SO ₄	Lb. of 66° acid in 1 cu. ft.	Melting (or freezing) point, °F.
41	1.3942	78.8	86.96	49.47	46.16	-35.0
42	1.4078	81.6	87.80	50.87	47.92	-31.0
43	1.4216	84.3	88.67	52.26	49.72	-27.0
44	1.4356	87.1	89.54	53.66	51.56	-23.0
45	1.4500	90.0	90.44	55.07	53.44	-20.0
46	1.4646	92.9	91.35	56.48	55.36	-14.0
47	1.4796	95.9	92.28	57.90	57.33	-15.0
48 .	1.4948	99.0	93.23	59 .32	59.34	-18.0
49	1.5104	102.1	94.20	60.75	61.40	-22.0
50	1.5263	105.3	95.20	62.18	63.52	-27.0
51	1.5426	108.5	96.21	63.66	65.72	-33.0
52	1.5591	111.8	97.24	65.13	67.96	-39.0
53	1.5761	115.2	98.30	66.63	70.28	-49.0
54	1.5934	118.7	99.38	68.13	72.66	-59.0
55	1.6111	122.2	100.48	69.65	75.10	00.0
						•
56	1.6292	125.8	101.61	71.17	77.60	
57	1.6477	129.5	102.77	72.75	80.23	
58	1.6667	133,3	103.95	74.36	82.95	- ^
59	1.6860	137.2	105.16	75.99	85.75	-7.0
60	1.7059	141.2	106.40	77.67	88.68	+12.6
61	1.7262	145.2	107.66	79.43	91.76	+27.3
62	1.7470	149.4	108.96	81.30	95.06	+39.1
63	1.7683	153.7	110.29	83.34	98.63	+46.1
64	1.7901	158.0	111.65	85.66	102.63	+46.4
65	1.8125	162.5	113.05	88.65	107.54	+33.1
66	1.8354	167.1	114.47	93.19	100.00	-29.0
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 $H_2SO_4 \cdot H_2O = 63.2^{\circ}B6$. approx. = 83.74 per cent. H_2SO_4 . $H_2SO_4 \cdot 2H_2O = 56.9^{\circ}B6$. approx. = 72.59 per cent. H_2SO_4 .

Temperature Corrections

For each degree in observed temperature above 60°F. add the correction to the observed specific gravity to get the true specific gravity at 60°. For each degree below 60°, subtract.

For 10°Bé. acid, 0.029 Bé. or 0.00023 sp. gr. per deg. F. For 20°Bé. acid, 0.036 Bé. or 0.00034 sp. gr. per deg. F. For 30°Bé. acid, 0.035 Bé. or 0.00039 sp. gr. per deg. F. For 40°Bé. acid, 0.031 Bé. or 0.00041 sp. gr. per deg. F. For 50°Bé. acid, 0.028 Bé. or 0.00045 sp. gr. per deg. F. For 60°Bé. acid, 0.026 Bé. or 0.00053 sp. gr. per deg. F. For 63°Bé. acid, 0.026 Bé. or 0.00057 sp. gr. per deg. F. For 66°Bé. acid, 0.025 Bé. or 0.00054 sp. gr. per deg. F.

SPECIFIC GRAVITY OF HYDROCHLORIC ACID

	SPECIFIC	GRAVITY (OF ILLUR	OCHLORI	C ACID		
Sp. gr. 15°	Degrees	Degrees	100 parts acid contain by weight				
40.	Baumé	Twaddell	Per cent.,	Per cent.,	Per cent.,	Per cent.	
	<u> </u>	[HCl	18° a id	20° acid	22° acid	
1.000	0.0	0.0	0.16	0.57	0.49	0.45	
1.005	0.7	1	1.15	4.08	3.58	3.25	
1.010	1.4	2	2.14	7.60	6.66	6.04	
1.015	2.1	2 3 4 5 6 7	3.12	11.08	9.71	8.81	
1.020	2.7	4	4.13	14.67	12.86	11.67	
1.025	3.4	5	5.15	18.30	16.04	14.55	
1.030	4.1	6	6.15	21.85	19.16	17.38	
1.035	4.7		7.15	25.40	22.27	20.20	
1.040	5.4	8	8.16	28.99	25.42	23.06	
1.045	6.0	9	9.16	32 .55	28.53	25 .88	
1.050	6.7	10	10.17	36.14	31.68	28.74	
1.055	7.4	.11	11.18	39.73	34.82	31.59	
1.060	8.0	12	12.19	43.32	37.97	34.44	
1.065	8.7	13	13.19	46.87	41.09	37.27	
1.070	9.4	14	14.17	50.35	44.14	40.04	
1.075	10.0	15	15.16	53.87	47.22	42.84	
1.080	10.6	16	16.15	57.39	50.31	45.63	
1.085	11.2	17	17.13	60.87	53.36	48.40	
1.090	11.9	18	18.11	64.35	56.41	51.17	
1.095	12.4	19	19.06	67.73	59.37	53.86	
1.100	13.0	20	20.01	71.11	62.33	56.54	
1.105	13.6	21	20.97	74.52	65.32	59.26	
1.110	14.2	22	21.92	77.89	68.28	61.94	
1.115	14.9	23	22.86	81.23	71.21	64.60	
1.120	15.4	24 25	23.82	84.64	74.20	67.31	
1.125	16.0	25 26	24.78	88.06	77.19	70.02	
1.130	16.5 17.1	26 27	25.75 26.70	91.50 94.88	80.21 83.18	72.76 75.45	
1.135 1.140	17.7	28	27.66	98.29	86.17	78.16	
1.145	18.3	2 9	28.61	101.67	87.66	79.51	
1.150	18.8	30	29.57	105.08	92.11	83.55	
1.155	19.3	31	30.55	108.58	95.17	86.32	
1.160	19.8	32	31.52	112.01	98.19	89.07	
1.165	20.3	33	32.49	115.46	101.21	91.81	
1.170	20.9	34	33.46	118.91	104.24	94.55	
1.175	21.4	35	34.42	122.32	107.22	97.26	
1.180	22.0	36	35.39	125.76	110.24	100.00	
1.185	22.5	37	36.31·	129.03	131.11	102.60	
1.190	23.0	38	37.23	132.30	115.98	105.20	
1.195	23.5	39	38.16	135.61	118.87	107.83	
1.200	24.0	40	39.11	138.98	121.84	110.51	

This table is taken from Lunge. Other authorities differ, giving in one case as much as 40.78 per cent. of HCl in 1.02 sp. gr. acid.

Specific Gravity of Nitric Acid at 15° Compared with Water at 4°

Sp. gr.		D	100 parts of acid contain by weight					
150	Degrees Baumé	Degrees Twaddell	N2O5	HNO:	38° acid	40° acid	48.5° acid	
1.000 1.005 1.010	0.0 0.7 1.4	0 1 2	0.08 0.85 1.62	1.00 1.90	1.89 3.60	0.16 1.61 3.07	0.10 1.03 1.95	
1.015 1.020 1.025	2.1 2.7 3.4	3. 4 5	2.39 3.17 3.94	2.80 3.70 4.60	5.30 7.01 8.71	4.52 5.98 7.43	2.87 3.79 4.72	
1.030 1.035 1.040 1.045 1.050	4.1 4.7 5.4 6.0 6.7	6 7 8 9 10	4.71 5.47 6.22 6.97 7.71	5.50 6.38 7.26 8.13 8.99	12.08 13.75 15.40	8.88 10.30 11.72 13.13 14.52	5.64 6.54 7.45 8.34 9.22	
1.055 1.060 1.065 1.070 1.075	7.4 8.0 8.7 9.4 10.0	11 12 13 14 15	8.43 9.15 9.87 10.57 11.27	9.84 10.68 11.51 12.33 13.15	18.64 20.23 21.80 23.35 24.91	15.89 17.25 18.59 19.91 21.24	10.09 10.95 11.81 12.65 13.49	
1.080 1.085 1.090 1.095 1.100	10.6 11.2 11.9 12.4 13.0	16 17 18 19 20	12.64 13.31 13.99	13.95 14.74 15.53 16.32 17.11	26.42 27.92 29.41 30.91 32.41	22.53 23.80 25.08 26.35 27.63	14.31 15.12 15.93 16.74 17.55	
1.105 1.110 1.115 1.120 1.125	13.6 14.2 14.9 15.4 16.0	21 22 23 24 25	16.00 16.67 17.34	17.89 18.67 19.45 20.23 21.00	33.89 35.36 36.84 38.31 39.77	28.89 30.15 31.41 32.67 33.91	18.35 19.15 19.95 20.75 21.54	
1.130 1.135 1.140 1.145 1.150	16.5 17.1 17.7 18.3 18.8	26 27 28 29 30	19.32 19.98 20.64	21.77 22.54 23.31 24.08 24.84	41.23 42.69 44.15 45.61 47.05	35.16 36.40 37.65 38.89 40.12	22.23 23.12 23.91 24.70 25.48	
1.155 1.160 1.165 1.170 1.175 1.180	19.3 19.8 20.3 20.9 21.4 22.0	31 32 33 34 35 36	22.60 23.25 23.90 24.54	27.88	48.49 49.92 51.36 52.80 54.22 55.64	41.35 42.57 43.80 45.03 46.24 47.45	26.26 27.04 27.82 28.59 29.36 30.13	

Specific Gravity of Nitric Acid at 15° Compared with Water at 4°. Continued

		W ATE	R AT 4	. 007	itinued			
Sp. gr.,	Sp. gr., Degrees Degrees			100 parts of acid contain by weight				
15° 4°	Baumé	Twaddell	N2O5	HNO ₃	38° acid	40° acid	48.5° acid	
1.185 1.190	$22.5 \\ 23.0$	37 38	25.83 26.47	1		48.66 49.87	30.90 31.67	
1.195 1.200	23.5 24.0	39 40	27.10 27.74	31.62	59.89	51.07 52.26	32.43 33.19	
$1.205 \\ 1.210$	$24.5 \\ 25.0$	41 42	28.36 28.99	1		53.23 54.21	33.94 34.69	
1.215 1.220	$25.5 \\ 26.0$	43 44	29.61 30.24	34.55	65.44	55.18 56.16	35.44 36.18	
1.225	26.4	45	30 .88	36 . 0 3	68.24	57.64	36.95	
1.230 1.235	26.9 27.4	46 47	32.17		71.08	59.13 60.61	37.72 38.49	
1.240 1.245	$egin{array}{c} 27.9 \ 28.4 \ 28.8 \end{array}$	48 ⁻ 49 50	32.82 33.47	39.05	73.96	61.84 63.07 64.31	39.27 40.05	
1.250 1.255	29.3	51		39.82 40.58		65.54	40.84 41.62	
1.260 1.265	$\frac{29.7}{30.2}$	52 53	35.44 36.09	41.34	78.30	66.76 67.99	42.40 43.18	
$1.270 \\ 1.275$	$\begin{array}{c} 30.6 \\ 31.1 \end{array}$	54 55	36.75 37.41	42.87 43.64	81.20 82.65	$69.23 \\ 70.48$	43.97 44.76	
1.280 1.285	31.5 32.0	56 57	38.07 38.73		84.11 85.57	.71.72 72.96	45.55 46.34	
1.290 1.295	32.4 32.8	58 59	39.39 40.05	45.95	87.03	74.21 75.45	47.13 47.92	
1.300	33.3	60	40.71			76.70	48.71	
1.305 1.310	33.7 34.2	61 62	41.37 42.06	49.07	92.94	77.94 79.25	49.50 50.33	
1.315	34.6 35.0	63 64	42.76 43.47	50.71	96.05	80.57	51.17 52.01	
1.325 1.330	35.4 35.8	65 66	44.17 44.89			83.22 84.58	52.85 53.71	
1.335 1.340	36.2 36.6	67 68	45.62 46.35	53.22	100.80	85.95 87.32	54.58 55.46	
1.345 1.350	37.0 37.4	69 70	47.08 47.82	54.93	104.04	88.71 90.10	56.34 57.22	
1.355	37.8	71	48.57			91.51	58.11	

Specific Gravity of Nitric Acid at 15° Compared with Water at 4°. Continued

Sp. gr.,	D	Dames	100 parts of acid contain by weight					
15°	Degrees Baumé	Degrees Twaddell	N2O5	HNO ₃	38° acid	40° acid	48.5° acid	
1.360 1.365 1.370	38.2 38.6 39.0	72 73 74	50.13 50.91	59.39	110.75 112.48	ľ	59.05 59.98 60.91	
1.375 1.380 1.385 1.390 1.395	39.4 39.8 40.1 40.5 40.8	75 76 77 78 79	51.69 52.52 53.35 54.20 55.07	61.27 62.24 63.23	114.20 116.04 117.88 119.75 121.68	97.38 98.95 100.51 102.12 103.76	61.85 62.84 63.84 64.85 65.90	
1.400 1.405 1.410 1.415 1.420	41.6 42.0 42.3 42.7	80 81 82 83 84	55.97 56.92 57.86 58.83 59.83	65.30 66.40 67.50 68.63	123.67 125.75 127.84 129.98	105.46 107.24 109.01 110.84 112.73	66.97 68.10 69.23 70.39 71.59	
1.425 1.430 1.435 1.440 1.445 1.450	43.4 43.8 44.1 44.4 44.8	85 86 87 88 89 90	60.84 61.86 62.91 64.01 65.13 66.24	72.17 73.39 74.68 75.98	136.68 138.99 141.44 143.90	114.63 116.55 118.52 120.61 122.71 124.81	72.80 74.02 75.27 76.59 77.93 79.26	
1.455 1.460 1.465 1.470 1.475	45.1 45.4 45.8 46.1 46.4	91 92 93 94 95		78.60 79.98 81.42 82.90	148.86 151.47 154.20 157.00 159.04	126.94 129.17 131.49 133.88 136.39	80.62 82.03 83.51 85.03 86.62	
1.480 1.485 1.490 1.495 1.500	46.8 47.1 47.4 47.8 48.1	96 97 98 99 100	78.52	87.70 89.60 91.60	162.97 166.09 169.69 173.48 178.19	138.97 141.63 144.70 147.93 151.99	88.26 89.95 91.90 93.95 96.50	
1.505 1.510 1.515 1.520	48.4 48.7 49.0 49.4	101 102 103 104	82.63 84.09 84.92 85.44	98.10 99.07		155.67 158.43 160.00 160.97	98.86 100.62 101.61 102.23	

Specific Gravity of Ammonia Water at 15°C. Compared with Water of 15°C.

			X	,	
Spr. gr.	Don sont	Correction	Sp. gr.	D4	Correction
15°	Per cent. NH ₄ OH	to sp. gr. for ±1°C.	15°	Per cent. NH ₄ OH	to sp. gr. for
15°	MHIOII	±1°C.	15°	MILLOH	± 1°C.
		} -			
1.000	0.00	0.00018	0.940	15.63	0.00039
0.998	0.45	0,00018	0.938	16.22	0.00040
0.996	0.91	0.00019	0.936	16.82	0.00041
	1.37	0.00019	0.934	17.42	0.00041
0.994	9			18.03	
0.992	1.84	0.00020	0.932	18.03	0.00042
0.990	2.31	0.00020	0.930	18.64	0.00042
0.988	2.80	0.00021	0.928	19.25	0.00043
0.986	3.30	0.00021	0.926	19.87	0.00044
	3.80	0.00021	$0.920 \\ 0.924$	20.49	0.00044
0.984		_ 1			
0.982	4.30	0.00022	0.922	21.12	0.00046
0.980	4.80	0.00023	0.920	21.75	0.00047
0.978	5.30	0.00023	0.918	22.39	0.00048
0.976	5.80	0.00024	0.916	23.03	0.00049
	4	0.00024	0.914	23.68	0.00050
0.974	6.30	1	_		
0.972	6.80	0.00025	0.912	24.33	0.00051
0.970	7.31	0.00025	0.910	24.99	0.00052
0.968	7.82	0.00026	0.908	25.65	0.00053
0.966	8.33	0.00026	0.906	26.31	0.00054
0.964	8:84	0.00027	0.904	26.98	0.00055
$\begin{array}{c} 0.364 \\ 0.962 \end{array}$	9.35	0.00028	0.902	27.65	0.00056
0.902	9.00	0.00025	0.502	21.00	0.0000
0.960	9.91	0.00029	0.900	28.33	0.00057
0.958	10.47	0.00030	0.898	29.01	0.00058
0.956	11.03	0.00031	0.896	29.69	0.00059
0.954	11.60	0.00032	0.894	30.37	0.00060
0.952	12.17	0.00033	0.892	31.05	0.00050
U. 3U2	14.11	0.0000	0.092	01.00	0.00000
0.950	12.74	0.00034	0.890	31.75	0.00061
0.948	13.31	0.00035	0.888	32.50	0.00062
0.946	13.88	0.00036	0.886	33.25	0.00063
0.944	14.46	0.00037	0.884	34.10	0.00064
0.942	15.04	0.00038	0.882	34.95	0.00065
U.U.Z	10.01	0.0000	0.002	02.00	0.0000

This and the nitric-acid table immediately preceding are reprinted by courtesy of the D. van Nostrand Co., New York, from Lunge's "Sulphuric Acid and Alkali."

SPECIFIC GRAVITY OF CAUSTIC POTASH SOLUTIONS AT 15°C.¹ (Grams KOH per 100 grams solution)

Sp. gr.	Per cent., KOH	Sp. gr.	Per cent., KOH	Sp. gr.	Per cent., KOH
1.036 1.077 1.124 1.175 1.230	5 10 15 20 25	1.288 1.349 1.411 1.475 1.539	30 35 40 45 50	1.604 1.667 1.729 1.790	55 60 65 70

¹ This and the succeeding 14 tables are from CREMER & BICKNELL'S Chemical and Metallurgical Handbook. They are originally from the work of Kohlrausch and Holborn, Gerlach, Schiff, etc.

SPECIFIC GRAVITY OF CAUSTIC SODA SOLUTIONS AT 15°C.

Sp. gr.	Per cent., NaOH	Sp. gr.	Per cent., NAOH	Sp. gr.	Per cent., NaOH
1.059 1.115 1.170 1.225 1.279	5 10 15 20 25	1.332 1.384 1.437 1.488 1.540	30 35 40 45 50	1.591 1.643 1.695 1.748	55 60 65 70

SPECIFIC GRAVITY OF HYDROFLUOSILICIC ACID AT 15°C.

Sp. gr.	Per cent., H ₂ SiF ₆	Sp. gr.	Per cent., H ₂ SiF ₆	Sp. gr.	Per cent., H ₂ SiF ₆
1.0407 1.0834 1.1281	5 10 15	1.1748 1.2235	20 25	1.2742 1.3162	30 34

Specific Gravity of Sodium Chloride Solutions at 15°C.

Sp. gr.	Per cent., NaCl	Sp. gr.	Per cent., NaCl	Sp. gr.	Per cent., NaCl
1.00725	1	1.07335	10	1.14351	19
1.01450	2	1.08097	11	1.15107	20
1.02174	3	1.08859	12	1.15931	21
1.02899	4	1.09522	13	1.16755	22
1.03624	5	1.10384	14	1.17580	23
1.04366	6	1.11146	15	1.18404	24
1.05108	7	1.11938	16	1.19228	25
1.05851	8	1.12730	17	1.20098	26
1.06593	9	1.13523	18	1.20433	26.3951

^{1 (}Sat.)

SPECIFIC GRAVITY OF CALCIUM CHLORIDE SOLUTIONS AT 15°C.

Sp. gr.	Per cent., CaCl ₂	Sp. gr.	Per cent., CaCl ₂	Sp. gr.	Per cent. CaCl ₂
1.01704	2	1.14332	16	1.28789	30 ·
1.03407	4	1.16277	18	1.31045	32
1.05146	6	1.18222	20	1.33302	34
1.06921	8	1.20279	22	1.35610	36
1.08695	10	1.22336	24	1.37970	38
1.10561	12	1.24450	26	1.40330	40
1.12427	$\overline{14}$	1.26619	28	1.41104	46.46

SPECIFIC GRAVITY OF ZINC CHLORIDE AT 19.5°C.

Sp. gr.	Per cent., ZnCl ₂	Sp. gr.	Per cent., ZnCl:	8p. gr.	Per cent., ZnCl ₂
1.045 1.091	5 10	1.238 1.291	25 30	1.488 1.566	45
1.137 1.187	15 20	1.352 1.420	35 40	1.650 1.740	55 60

SPECIFIC GRAVITY OF FERRIC CHLORIDE SOLUTIONS AT 17.5°C.

Sp. gr.	Per cent., FeCl:	Sp. gr.	Per cent., FeCl ₃	Sp. gr.	Per cent. FeCl:
1.0146	2	1.1746	22	1.3870	42
1.0292	4	1.1950	24	1.4118	44
1.0439	6	1.2155	26	1.4367	46
1.0587	8	1.2365	28	1.4617	48
1.0734	10	1.2568	30	1.4867	50
1.0894	12	1.2778	32	1.5153	52
1.1054	14	1.2988	34	1.5439	54
1.1215	16	1.3199	36	1.5729 .	56
1.1378	18	1.3411	38	1.6023	58
1.1542	20	1.3622	40	1.6317	60

Specific Gravity of Cuprous Chloride Solutions at 17.5°C.

Sp. gr.	Per cent., CuCl ₂	Sp. gr.	Per cent., CuCl ₂	Sp. gr.	Per cent., CuCl ₂
1.0182 1.0364 1.0548 1.0734 1.0920 1.1178 1.1436	2 4 6 8 10 12 14	1.1696 1.1958 1.2223 1.2501 1.2779 1.3058 1.3338	16 18 20 22 24 26 28	1.3618 1.3950 1.4287 1.4615 1.4949 1.5284	30 32 34 36 38 40

SPECIFIC GRAVITY OF LEAD ACETATE SOLUTIONS AT 15°C.

Per cent., PbA ₂	Sp. gr.	Per cent., PbA ₂	Sp. gr.	Per cent., PbA ₂	
2	1.1384	20	1.2967	38	
4	1.1544	22	1.3163	40	
1	1.1704	24	1.3376	42	
8	1.1869	26	1.3588	44	
10	1.2040		1.3810	46	
12	1.2211	30	1.4041	48	
14	1.2395	32	1.4271	50	
16	1.2578	34			
18	1.2768	36			
	PbA ₂ 2 4 6 8 10 12 14 16	PbA ₂ 2 1.1384 4 1.1544 6 1.1704 8 1.1869 10 1.2040 12 1.2211 14 1.2395 16 1.2578	PbA: Sp. gr. PbA: 2 1.1384 20 4 1.1544 22 6 1.1704 24 8 1.1869 26 10 1.2040 28 12 1.2211 30 14 1.2395 32 16 1.2578 34	PbA; Sp. gr. PbA; Sp. gr. 2 1.1384 20 1.2967 4 1.1544 22 1.3163 6 1.1704 24 1.3376 8 1.1869 26 1.3588 10 1.2040 28 1.3810 12 1.2211 30 1.4041 14 1.2395 32 1.4271 16 1.2578 34	

SPECIFIC GRAVITY OF FERRIC SULPHATE SOLUTIONS AT 17.5°C.

Sp. gr. Per cent., Fe ₂ (SO ₄) ₃		Sp. gr. Per cent., Fe ₂ (SO ₄) ₃		Sp. gr.	Per cent., Fe ₂ (SO ₄) ₃	
1.0170 1.0340 1.0512 1.0684 1.0854 1.1042 1.1230 1.1424 1.1624 1.1826	2 4 6 8 10 12 14 16 18 20	1.2066 1.2306 1.2559 1.2825 1.3090 1.3368 1.3646 1.3927 1.4217	22 24 26 28 30 32 34 36 38 40	1.4824 1.5142 1.5468 1.5808 1.6148 1.6508 1.6868 1.7241 1.7623 1.8006	42 44 46 48 50 52 54 56 58 60	

SPECIFIC GRAVITY OF FESO₄·7H₂O; CuSO₄·5H₂O and ZnSO₄·-7H₂O Solutions at 15°C.

Sp. gr.	Per cent., ZnSO4.7H ₂ O	Sp. gr.	Per cent., CuSO4·5H ₂ O	Sp. gr.	Per cent., FeSO ₄ .7H ₂ O
1.0288	5	1.0126	2	1.011	2
1.0593	10	1.0254	4	1.021	4
1.0905	15	1.0384	6	1.032	6
1.1236	20	1.0516	8	1.043	8
1.1574	25	1.0649	10	1.054	10
1.1933	30	1.0785	12	1.065	12
1.2310	35	1.0923	14	1.082	15
1.2709	40	1.1063	16	1.112	20
1.3100	45	1.1208	18	1.143	25
1.3522	50	1.1354	20	1.174	30
1.3986	55	1.1501	22	1.206	35
1.4451	60	1.1659	24	1.239	40

130 METALLURGISTS AND CHEMISTS' HANDBOOK

SPECIFIC GRAVITY OF SODIUM CARBONATE SOLUTIONS AT 15°C,.

Sp. gr. Per cent., Na ₂ CO ₃		Sp. gr. Per cent., Na ₂ CO ₂		Sp. gr.	Per cent,. Na ₂ CO ₃	
1.01050 1.02101 1.03151 1.04201 1.05255	. 1 2 3 4 5	1.06309 1.07369 1.08430 1.09500 1.10571	6 7 8 9 10	1.11655 1.12740 1.13845 1.14950 1.15360	11 12 13 14 14 14.354	

Specific Gravity of Dihydrogen Sodium Arsenate Solutions at 17°C.

Sp. gr.	Per cent., H2NaAsO4·H2O	Sp. gr.	Per cent., H ₂ NaAsO ₄ ·H ₂ O
1.0226	4.22	1.9038	16.88
1.0460	8.44	1.1186	21.10
1.0577	10.55		

Specific Gravity of Solutions of Trisodium Arsenate at 17°C.

Sp. gr.	Na ₃ AsO ₄ ·12H ₂ O	Sp. gr.	Na:AsO4·12H2O
1.0193	4.40	1.0812	17.60
1.0393	8.80	1.1035	22.06
1.0495	11.00		

Specific Gravity of Disodium Arsenate Solutions at 14°C.

1.0169	4	1.0714	16
1.0344	8	1.1102	23.9
1.0525	12	1.1722	35.9

DENSITIES OF SOME SALINE AND ACID SOLUTIONS¹

	T	Percentage of salt						
Substances	Tempera- tures	5 10		20	30	40	60	
Potassium chloride	15.0°C. 15.0°C. 19.5°C. 19.5°C. 19.5°C. 15.0°C. 15.0°C. 15.0°C. 15.0°C. 13.0°C. 14.0°C. 13.0°C.	1.015 1.038 1.035 1.036 1.031 1.020 1.042 1.044 1.053 1.045 1.034 1.033 1.036	1.030 1.078 1.076 1.066 1.064 1.042 1.089 1.092 1.107 1.071 1.053 1.072	1.172 1.157 1.164 1.140 1.135 1.086 1.196 1.192 1.213	1.279 1.253 1.269 1.222 1.131 1.321 1.300	1.407 1.393 1.313 1.179 1.476 1.417	1.730 1.283 1.916	

^{1 &}quot;Annuaire pour 1914, Bureau des Longitudes."

BOILING POINTS

BOILING POINTS OF THE METALS

	Visible ebullition	Volatili- zation com- mences		Visible ebullition	Volatili- zation com- mences
Antimony. Aluminum. Bismuth. Chromium. Copper ¹ . Gold. Indium. Iron. Iridium. Lead. Lithium. Magnesium. Manganese. Mercury. Molybdenum. Nickel.	1420°C.2 1800°C.2 1440°C.2 2200°C.2 2310°C.3 2100°C.3 1000°C. 2450°C.2 2850°C.5 1525°C.2 500°C.6 1120°C.6 1900°C.3 357°C.6 3350°C.5 2450°C.5	1420°C.3 960°C.3 970°C.3	Osmium. Palladium. Platinum. Rhodium. Rubiqium. Ruthenium Selenium. Silicon. Silver. Tantalum. Tellurium Tin7. Titanium. Thallium. Uranium. Wolfram.	2950°C.\$ 2540°C.\$ 2650°C.\$ 2750°C.\$ 696°C. 2780°C.\$ 690°C.\$ 1955°C.\$ 1280°C.\$ 1280°C.\$ 3700°C.\$	1350°C. 850°C. 2200°C. 880°C.

According to Tiede and Birnbräuer, copper boils at 2000°.

According to H. C. Greenwood.

According to Tiede and Birnbräuer, Zeit. anorg. chem., 1914, p. 129.

Dulong and Petit.

Watts, Tr. Electrochem. Soc., 1907, p. 141.

Richards, "Metallurgical Calculations."

Given by Carnelly as 1550°C.

	Beginning of evaporation in vacuo1	Boiling point in vacuo1	Boiling-poin 760° mm. ¹	
Bismuth	270°C.	993°C.	-1440°C.	
Cadmium	156	450	749	
Mercury	-40	155	357	
Potassium	63	365	667	
Silver	680	1360	1955	
$\mathbf{Sodium} \ldots \ldots$	98	418	742	
Z inc	184	550	920	
Sulphur			444.5	

¹ According to H. C. GREENWOOD.

BOILING POINTS OF THE NON-METALLIC ELEMENTS¹

	Visible ebullition		Visible ebullition
Argon. Arsenic sublimes. Boron sublimes(?) Bromine. Carbon. Chlorine. Fluorine. Helium.	450.0°C. 3500.0°C. 63.0°C. 3700.0°C. - 33.6°C. - 187.0°C.	Hydrogen Iodine Krypton Neon Nitrogen Oxygen Phosphorus Xenon	184.4°C. - 151.7°C. - 239.0°C. - 195.7°C. - 182.9°C. 287.0°C.

¹ J. W. Richards, "Metallurgical Calculations" and Kaye and Laby's "Physical and Chemical Constants."

Boiling Points of Some Common Compounds

Boiling Point of Water under Various Barometric Pressures

Pressure mm. of mercury	0	1	2	3	4	5	6	7	8	9
680 690 700 710 720	°C. 96.91 97.32 97.71 98.11 98.49	97.75 98.14	97.40 97.79	97.44 97.83 98.22	97.48 97.87 98.26	97.52 97.91 98.30	97.56 97.95 98.34	97.59 97.99 98.38	97.63 98.03 98.42	98.07 98.45
730 740 750 760 770 780	100.37	99.29 99.67 100.03 100.40	100.07 100.44	99.37 99.74 100.11 100.47	99.41 99.78 100.15 100.51	99.44 99.81 100.18 100.55	99.48 99.85 100.22 100.58	99.52 99.89 100.26 100.62	99.56	99.59 99.96 100.33 100.69

Regnault gives slightly different values, as shown in the following table:

BOILING POINT OF WATER AT DIFFERENT BAROMETER READINGS (REGNAULT)

Boiling point	Millimeters	Boiling point	Millimeters
100.4°C.	771.95	99.4°C.	743.83
100.3°	768.20	99.3°	741.16
100.2°	765.46	99.2°	738.50
100.1°	762.73	99.1°	735.85
100.0°	760.00	99.0°	733.21
99.9°	757.28	98.9°	730.58
99.8°	754.57	98.8°	727.96
99.7°	751.87	98.7°	725.35
99.6°	749.18	98.6°	722.75
99.5°	746.50	98.5°	720.15

BOILING POINTS OF NITRIC ACID SOLUTIONS IN WATER (160 mm. pressure)

Per cent., HNO:	Boiling point, degrees C.	Per cent., HNO:	Boiling point, degrees C.
19.37	103.56	67.74	121.67
30.43	108.08	68.18	121.79
41.38	112.59	69.24	121.80
51.63	116.85	71.10	121.60
56.01	118.88	73.56	120.75
59.77	120.06	80.50	115.45
63.89	121.27	85.51	108.12
65.17	121.66	90.06	102.03
		95.45	95.42

¹ Creighton and Githens, "Journal of the Franklin Institute," February, 1915.

		Rectval	VALENT		BVAPORATION		PROM AND	2	212 D	Duosans ¹	, ,	Ì	
Pempuratura				to same	el mese	pounds	absolu		esturated.	E			Temperature
of feed water, dagrees F.	=	17	1	1 11	:3	29	2	3	8	100	_	130	of level water.
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\$1.0881 31.0830 31.0820	31.080 221.079 221.078 1.077	11.075 11.073 1.073 1.072	11111 10869 10869	771.065 771.065 1.065 1.065 1.065	00000000000000000000000000000000000000
31.0865 1.0813 51.0803	1.079 1.078 1.077 1.076 1.076	31.0741 21.0731 21.0721 21.0710 11.0700	1.0690 1.0669 1.0669 1.0659	1.063 1.062 1.061 1.060 1.059	11.055 1.055 1.055 1.055 1.055
11.0846 11.0795 11.0785	1.0774 11.0764 11.0754 11.0743	1.0723 1.0712 1.0702 1.0692 1.0681	1.0671 1.0661 1.0650 1.0640 1.0630	1.0619 1.0609 11.0599 11.0588	055 055 055 055 050 050 050 050 050 050
1.0826 1.0774 1.0764	1.0754 1.0743 1.0733 1.0723	1.0702 1.0692 1.0681 1.0681 1.0671	1.0650 1.0640 1.0630 1.0639 1.0609	1.0599 1.0588 1.0578 1.0568 1.0568	1.0547 1.0537 1.0526 1.0516 1.0506 1.0495 1.0485 1.0464
1.0802 1.0751 1.0740	1.0730 1.0720 1.0709 1.0699 1.0689	1.0658 1.0668 1.0658 1.0647 1.0637	1.0627 1.0616 1.0606 1.0596 1.0585	1.0575 1.0565 1.0554 1.0544 1.0534	1.0523 1.0513 1.0503 1.0492 1.0461 1.0461
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1.0653 1.0653 1.0642	1.0632 1.0622 1.0611 1.0601	1.0580 1.0570 1.0560 1.0549 1.0539	1.0529 1.0518 1.0508 1.0498	1.0477 1.0457 1.0456 1.0446	1.0425 1.0415 1.0405 1.0384 1.0384 1.0363 1.0343 1.0332
1.0655 1.0603 1.0593	1.0583 1.0572 1.0562 1.0552 1.0541	1.0531 1.0521 1.0510 1.0500 1.0490	1.0479 1.0469 1.0458 1.0448	1.0428 1.0417 1.0397 1.0386	1.0376 1.0366 1.0355 1.0324 1.0304 1.0293 1.0293
1.0589 1.0537 1.0527	1.0517 1.0506 1.0496 1.0486 1.0475	1.0465 1.0455 1.0434 1.0424	1.0413 1.0403 1.0393 1.0382 1.0372	1.0362 1.0351 1.0341 1.0331	1.0310 1.0289 1.0269 1.0268 1.0258 1.0248 1.0227 1.0227
1.0489 1.0437 1.0427	1.0417 1.0406 1.0396 1.0386 1.0375	1.0365 1.0344 1.0344 1.0334 1.0324	1.0313 1.0303 1.0293 1.0282 1.0272	1.0262 1.0251 1.0241 1.0231 1.0220	1.0210 1.0200 1.0101 1.0169 1.0168 1.0158 1.0138 1.0127 1.0127 1.0127
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ROTTING	AND	MELTING	POINTS	OF	ORGANIC	Rontes!	
DOILING	AND	TATESTALING	TUINTS	UF	URGANIC	DODIES.	

•	Melting point,	Boiling point, C.°		Melting point, C.°	Boiling point, C.°
Acetone		57.1	Camphor	177.7	205.0
Acid:	10 71	118.1	Chloroform	$\begin{bmatrix} -63.2 \\ -34.4 \end{bmatrix}$	-61.2 -20.7
Acetic		249.1	Cyanogen Ethane	-177.5	- 20.7 - 93.0
Bensoic			Ether	-117.6	34.6
Butyric	_ 3.12	(about)	Ethylene	-169.0	-102.5
Carbonic	- 78.2	- 57.0	Ethylene dibro-	-105.0	-102.5
Formic					160.0
Stearic		100.0		- 20.0	291.0
Succinic			l ~ ~~ ~	-184.11	
Alcohol:	100.0	, · · · · · · · · · · · · · · · · · · ·	Naphthalene		217.72
Amyl		132.0	Nitrobenzene	5.17	
Ethyl	-130.0	78.2	Phenol		181.4
201191111111	(about)		Carbon disul-		-0
Methyl		64.7	phide		46.3
Aldehyde		20.8	Carbon tetra-		
Aniline	- 6.0	183.7	chloride	22.0	76.7
Bensene		80.0	Toluene	- 98.0	110.0

¹ For the melting points of the elements, see p. 254. For melting points of inorganic compounds, see p. 216 et seq. This table was taken from the "Annuaire pour 1914, Bureau des Longitudes."

The Thermal Properties of Steam

Probably the most critical investigation yet made of the thermal properties of steam was that of G. A. Goodenough of the University of Illinois, from whose work the following formulas are taken:

The relation found between the pressure and temperature of the steam is as follows:

$$\log p = 10.5688080 - \frac{4876.643}{T} - 0.0155 \log T$$
$$- 0.00406258T + 0.00000400555T^{2}$$
$$- 0.00002 \left\{ 10 - 10 \left(\frac{t - 370}{100} \right)^{2} + \left[\frac{t - 370}{100} \right] \right\}$$

where p is the pressure in pounds per square inch, and T the absolute temperature in Fahrenheit units, while t is the temperature in Fahrenheit degrees. The absolute zero is taken as -459.6°F. For the specific volume of the steam Professor Goodenough gives the expression:

$$v - 0.017 = 0.59465 \frac{T}{p} - (1 + 0.05129p^{1/2}) \frac{C_1}{T^4}$$

where v denotes the volume in cubic feet per pound, and $\log C_1 = 10.82500$. The "heat content" of steam at different temperatures and pressures is:

$$i = 0.320T + 0.000063T^{2} - \frac{23583}{T} - \frac{C_{3}p(1 + 0.0342p^{\frac{1}{2}})}{T^{4}} + 0.00333p + 948.7$$

where

 $\log C_8 = 10.79155$

The entropy of superheated steam is given by the relation:

$$s = 0.73683 \log T + 0.000126T - \frac{11.7915}{T^2} - 0.25355 \log p - \frac{C_4 p(1 + 0.0342p)}{T^5} - 0.08085$$

where

$$\log C_4 = 10.69464$$

The thermal properties of steam at very high pressures and temperatures are stated to be as follows:

T	D	37-1	Weight	Heat co	ntent of	Totont
Tempera- ture, degrees F.	Pressure, lb. per sq. in.	Volume of 1 lb., cu. ft.	of 1 cu. ft., lb.	Liquid, B.t.u.	Vapor, B.t.u.	Latent heat, B.t.u.
600.0	1540.4	0.272	3.68	604.5	1164	560
$\begin{array}{c} 620.0 \\ 640.0 \end{array}$	1658.7 2056.6	0.241 0.187	4.15 5.35	633.0 663.0	1151 1136	518 473
660.0 680.0	2360.8 2699.1	0.151 0.118	6.63 9.86	700.0 745.0	1112 1080	412 335
700.0 706.3	3074.5 3200.0	$0.080 \\ 0.048$	12.46 20.92	823.0 921.0	1016 921	193 0
706.3	3200.0	0.048	20.92	921.0	921	0

The following note and table, giving the constants of steam at ordinary temperatures, is from "Lubricants," 1914, p. 10.

The temperature of steam in contact with water depends upon the pressure under which it is generated. At ordinary atmospheric pressure (14.7 lb. per square inch) the temperature is 212°F., but as the pressure increases the temperature of both the steam and the water also increases.

Saturated steam is steam of the temperature due to its pressure, while superheated steam is steam heated to a temperature above that due to its pressure. Saturated steam cannot be cooled except by lowering its pressure. Steam in contact with water cannot be heated above the temperature due to its pressure.

The latent heat or heat of vaporization is obtained by subtracting from the total heat at any given temperature the heat of the liquid. Since the "total heat" is greater as the pressure increases, it will take more heat and consequently more fuel, to make a pound of steam as the pressure increases.

TABLE OF PROPERTIES OF SATURATED STEAM¹

Pressure in pounds per	ture,	units abo	at in heat ove 32°F.	Heat of vaporization of latent heat (L)	Density or weight in pounds	Volume in cubic feet of	Factor of equivalent evapor-
square inch	Fahren- heit	In the steam (H)	In the water (h)	in heat units $L = H - h$	of 1 cu. ft.	1 lb.	ation at 212°F.
1 2 3 4 5	101.99 126.27 141.62 153.09 162.34	1120.5 1125.1 1128.6	70.0 94.4 109.8 121.4 130.7	1043.0 1026.1 1015.3 1007.2 1000.8	0.00299 0.00576 0.00844 0.01107 0.01366	173.6 118.5 90.33	0.9661 0.9738 0.9786 0.9822 0.9852
6 7 8 9 10	170.14 176.90 182.92 188.33 193.25	1135.9 1137.7 1139.4	138.6 145.4 151.5 156.9 161.9	995.2 990.5 986.2 982.5 979.0	0.01622 0.01874 0.02125 0.02374 0.02621	53.39 47.06	0.9876 0.9897 0.9916 0.9934 0.9949
15 20 25 30 35	213.03 227.95 240.04 250.27 259.19	1151.5 1155.1	181.8 196.9 209.1 219.4 228.4	965.1 954.6 946.0 938.9 932.6	0.03826 0.05023 0.06199 0.07360 0.08508		1.0003 1.0051 1.0099 1.0129 1.0157
40 45 50 55 60	267.13 274.29 280.85 286.89 292.51	1165.6 1167.6	236.4 243.6 250.2 256.3 261.9	927.0 922.0 917.4 913.1 909.3	0.09644 0.1077 0.1188 0.1299 0.1409	10.37 9.285 8.418 7.698 7.097	1.0182 1.0205 1.0225 1.0245 1.0263
65 70 75 80 85	297.77 302.71 307.38 311.80 216.02	1174.3 1175.7 1177.0	267.2 272.2 276.9 281.4 285.8	905.5 902.1 898.8 895.6 892.5	0.1519 0.1628 0.1736 0.1843 0.1951	6.583 6.143 5.760 5.426 5.126	1.0280 1.0295 1.0309 1.0323 1.0337
90 95 100 105 110	320.04 323.89 327.58 331.13 334.56	1182.9	290.0 294.0 297.9 301.6 305.2	889.6 886.7 884.0 881.3 878.8	0.2058 0.2165 0.2271 0.2378 0.2484	4.859 4.619 4.403 4.205 4.026	1.0350 1.0362 1.0374 1.0385 1.0396
115 120 125 130 140	337.86 341.05 344.13 347.12 352.85	1186.0	308.7 312.0 315.2 318.4 324.4	876.3 874.0 871.7 869.4 865.1	0.2589 0.2695 0.2800 0.2904 0.3113	3.862 3.711 3.571 3.444 3.212	1.0406 1.0416 1.0426 1.0435 1.0453
150 160 170 180 190	358.26 363.40 368.29 372.97 377.44	1192.8	330.0 335.4 340.5 345.4 350.1	861.2 857.4 853.8 850.3 847.0	0.3321 0.3530 0.3737 0.3945 0.4153	3.011 2.833 2.676 2.535 2.408	1.0470 1.0486 1.0502 1.0517 1.0531
200 225 250 275 300	381.73 391.79 400.99 409.50 417.42	1198.4 1201.4 1204.2 1206.8 1209.3	354.6 365.1 374.7 383.6 391.9	843.8 836.3 829.5 823.2 817.4	0.4359 0.4876 0.5393 0.5913 0.644	2.294 2.051 1.854 1.691 1.553	1.0545 1.0576 1.0605 1.0632 1.0657
325 350 375 400 500	424.82 431.90 438.40 445.15 466.57	1215.7 1217.7	399.6 406.9 414.2 421.4 444.3	811.9 806.8 801.5 796.3 779.9	0.696 0.748 0.800 0.853 1.065	1.437 1.337 1.250 1.172 0.939	1.0680 1.0703 1.0724 1.0745 1.0812

¹ Kent, "Mechanical Engineer's Pocket-Book," New York, 1913, p. 836.

VAPOR TENSIONS OF VARIOUS METALS¹
(As calculated by J. W. RICHARDS, "Metallurgical Calculations")

(As calculate	a by J. W	. RICHAR	ds, Me	tanurgica	i Calculatio	ns'')
Venez tension	Mercury	Lead	Silver	Cald	Cadarina	72
Vapor tension, mm. of mercury	at C.°	at C.°	at C.º	Gold at C.°	Cadmium at C.°	Zinc at C.
mm. Of mercury	200.	at C.	AU 0.	at C.	at C.	at C.
				<u>, </u>		
0.0002	0	625	729	942	183	248
0.0005	10	658	766	987	200	267
0.0013	20	691	802	1031	216	286
0.0029	80 40	724	839	1075	233	305
0.0063	20	757	876	1120	250	324
0.013	50	790	913	1165	267	344
0.026	60	822	949	1209	283	363
0.050	70	855	986	1254	300	382
0.093	80	888	1023	1298	317	401
0.165	90	921	1059	1343	333	420
0.007	100	074	1000	1007	1	
0.285	100	954	1096	1387	350	439
0.478	110 120	987	1133	1432	367	458
0.779 1.24	130	1020 1053	1169 1206	1476 1520	383 400	477
1.93	140	1086	1243	1565	417	496 516
1.80	140	1000	1420	1000	414	910
2.93	150	1119	1280	1611	433	535
4.38	160	1151	1316	1654	450	554
6.41	170	1184	1353	1699	467	573
9.23	1801	12171	13901	17431	4831	5921
14.84	190	1250	1427	1788	500	611
10.00	900	1000	1400	1020	217	620
19.90	200 210	1283	1463	1832 1877	517 533	630 649
26.25 34.70	220	1316 1349	1500 1537	1921	550	668
45.35	230	1382	1574	1965	567	687
58.82	240	1415	1610	2010	584	706
00.02	1 -10	2110	1010	2010	00.	
7 5.75	250	1448	1647	2055	600	726
96.73	260	1480	1684	2099	617	745
123.0	270	1513	1720	2144	634	764
155.0	280	1546	1757	2188	650	783 .
195.0	290	1579	1794	2233	667	802
242.0	300	1612	1830	2277	684	821
300.0	310	1645	1867	2322	700	840
369.0	320	1678	1904	2366	717	859
451.0	330	1711	1941	2410	734	878
548.0	340	1744	1977	2455	750	897
445 4		4	000	0.00		0.5
663.0	350	1777	2014	2500	767	915
76 0.0	3572	18002	20402	25302	7802	9302
		1	Atmosphe	eres pressi	ıre	
2.1	400	1951	2197	2722	851	1012
4.25	450	2116	2380	2945	934	1107
8.0	500	2280	2564	3167	1018	1203
13.8	550	2445	2747	3390	1101	1298
22.3	600	2609	2931	3612	1185	1394
34.0	650	2774 .	3114	3835	1268	1489
	* ****	0000	0000	4025	1050	1 505
50.0	700	2938	3298	4057	1352	1585
72.0	750 ·	3103	3481	4280	1435	1680 1776
102.0	800 850	3267 3 4 36	3665 3848	4502 4725	1519 1602	1871
137.5 1 62 .0	880	3525	3958	4858	1652	1928
102.0	660	UULU	0000	#000	1002	
			· · · ·		_	

<sup>Approximate boiling points in vacuo.
Approximate boiling points at normal pressures.</sup>

MEAN VALUES OF THE VAPOR PRESSURE OF AS2O2

Temper- ature	Vapor pressure	As ₂ O ₃ per 1000 cu. ft. of gas	Temper- ature	Vapor pressure	As ₂ O ₃ per 1000 cu. ft. of gas
°C. 100 120 140 160 180 200	Mm. of mer- cury 0.000266 0.00180 0.01035 0.0473 0.186 0.653	Pounds 0.000386 0.00261 0.0150 0.0685 0.270 0.947	°C. 220 240 260 280 300	Mm. of mercury 2.065 5.96 15.7 38.5 89.1	Pounds 3.00 8.71 23.2 58.6 144.0

This table, from "Tech. Paper 81," U. S. Bureau of Mines, may be used as a rough basis for the calculation of arsenic in smeltery gases. The vapor pressure of arsenic volatilized from flue dust at a given temperature is about half of the value in the table for that temperature. The heat of sublimation of arsenic varies from about 28,000 gram-cal. at 110°C. to about 25,000 at 290°C. per gram-molecule of arsenic (396 grams).

CRYOHYDRATES. SALT AND ICE MIXTURES1

Name of salt	Cryohydric point, degrees C.	Percentage an- hydrous salt in ice mixture
Calcium chloride	-55.0	29.8
Sodium bromide		41.33
Sodium chloride		23.60
Sodium nitrate	.	40.80
Ammonium chloride		19.27
Magnesium sulphate		21.86

1" General Electric Review" 1915.

Cooling Mixtures of Salt and Water¹

	Mixed with	Tempera	ture falls
	100 parts water	From C.°	To C.º
Alum-crystallized	14	10.8°	9.0
Ammonium carbonate	30	15.3	3.2
chloride	30	13.3	-5.1
nitrate	60	13.6	-13.6
sulphate	75	13.2	6.8
sulphocyanate		13.2	-18.0
Calcium chloride crystallised	250	10.8	-12.4
Magnesium sulphate crystallized	85	11.1	-3.1
Potassium chloride	30	13.2	-3.0
iodide		10.8	-11.7
nitrate	16	13.2	-3.0
sulphate	12	14.7	-11.7
sulphocyanate		10.8	-23.7
Sodium acetate, cryst	85	10.7	-4.7
carbonate, cryst	40	10.7	1.6
chloride	36	12.6	10.1
hyposulphite, cryst	110	10.7	-8.0
nitrate	75	13.2	-5.3
phosphate, cryst		10.8	7.1
sulphate, cryst	20	12.5	5.7

¹ CREMER and BICKNELL'S "Chemical and Metallurgical Hand Book."

Capillary Constants for Molten Metals (Given by Landolt, $r \times h = a^2$)¹

These are the products of the rise (or depression) of the metal by the radius of the tube, or the rise or depression in tubes of 1 cm. radius.

Metal	S. W. Smith	Quincke	Siedentopf	Grunmach	
Selenium		4.41	ł.		
Antimony	8.65	9.90	• • • • • • • • • • • • • • • • • • •	• • • • • • • • •	
Bismuth	$\left\{\begin{array}{c} 6.91 \\ 7.53 \end{array}\right\}$	9.76	8.755		• • • • • • • • • •
Lead	$\left\{ \begin{array}{c} 8.36 \\ 8.12 \end{array} \right\}$	9.98	9.778	9.060	
Mercury	$\left\{ egin{array}{c} 6.72 \\ 6.73 \\ 14.57 \end{array} \right\}$	8.234		$\left\{\begin{array}{c} 7.39 \\ 6.09 \end{array}\right\}$	Stöckle 6.548
Tin	14.55 14.97	19.43	17.87	10.27	• • • • • • • • • •
Cadmium	(.22.00)	19.8	21.25		
Aluminum	45.09		values give		
Zine	$\left\{ egin{array}{c} 25.05 \ 24.54 \ \end{array} \right\}$	${28.6 \atop 30.6}$	· · · · · · · · ·	• • • • • • • • •	
Silver	18.57 18.47	15.94	• • • • • • • • • • • •	• • • • • • • •	Gradenwitz 14.5
Copper	$\left\{ egin{array}{c} 28.23 \ 29.47 \ \end{array} \right\}$	14.44		• • • • • • • • •	Heydweiller
Gold	11.29	(05 01)			6.90
Iron		$\left\{ egin{array}{c} 25.81 \\ 27.14 \end{array} ight\}$	• • • • • • • •	• • • • • • • •	

Comparison of Values for Surface Tensions of Metals Obtained by Various Workers

(Given by LANDOLT)1

Metal	S.W.Smith	Quincke	Siedentopf	Grunmach	
	Dynes per	Dynes per	Dynes per	Dynes per	Dynes per
g.1	centimeter	centimeter	centimeter	centimeter	centimeter
Selenium	274.0	92.5 317.2	 • • • • • • • • •	• • • • • • • • •	
Antimony Bismuth	346.0	464.9	429.5		• • • • • • • • • •
Digiti di di di di di di di di di di di di di	340.0	(535.9	509.5	````	
Lead	424.5	1 1		(Agomg.	
20000		457 mg.		mm.	
3.6		mm.	mm.	7,401.03	a
Mercury	447.5	547.2		{491.2}	Stöckle
		681.2	612.4	\ 405.0 \ 352 \	435.6
Tin	480.0			359 }	
A 1111	400.0	$\frac{598 \frac{\text{mg.}}{\text{mm}}}{1}$	624 mg.	000)	
Aluminum	500 O	mm.		11	
Aluminum	520.0		values record	160	• • • • • • • • • • • •
Zinc	707.5	$\left\{ egin{array}{c} 967.4 \\ 1103.7 \end{array} \right\}$			
Cadmium		815.0	832.0		
Cadmidm		010.0	302.0		Gradenwitz,
Silver	858.0	782.4			751.0
Gold	1018.0	581.0			Heydweiller
					612.2
Copper	1178.0				 • • • • • • • • • • • •
Nickel; iron.	1350.0				

¹SYDNEY W. SMITH, paper before the Institute of Metals, September, 1914.

The surface tensions of liquid metals are periodic functions of their atomic weights. In each period the surface tension decreases slightly, the metal of lowest atomic weight having the highest surface tension.

Heat Conductivity (K)

A plate of the given substance 1 cm. thick, with parallel sides having a difference in temperature of 1°C., conducts enough heat per square centimeter per second to heat K grams of water from 0° to 1°C. The table is one compiled from various sources. See also Hering's Thermal Resistivity Table on p. 148.

Metals	Temperature, degrees C.	K	
Aluminum	18	0.504	
Aluminum	100	0.492	
Aluminum	160	0.514	
Antimony	0 to 30	0.044	
Antimony	100	0.040	
Bismuth) 0	0.0177	
Bismuth	100	0.0161	
Bismuth.	186	0.025	
Brass, red		0.2460	
Brass, red	100	0.2847	
Brass, yellow		0.2041	
Brass, yellow	100	0.2540	
Cadmium	0	0.02213	
Cadmium	100	0.02045	
Cadmium		0.239	
	0	1.0405	
	100	0.908	
	160	1.079	
Copper (containing iron)	0 to 30	0.954	
Copper (phosphor bronze)		0.7198	
Copper (phosphor bronze)	100	0.7226	
German silver	31	0.081	
German silver	100	0.0887	
Gold	18	0.700	
ron	160	0.152	
ron, wrought (1 per cent. C.)		0.144	
ron, wrought		0.1772	
ron, wrought		0.1567	
ron, wrought		0.1447	
ron, wrought		0.1357	
ron, wrought		0.1240	
ron (pure)	18	0.161	
(ron (Bessemer steel)		0.0964	
[ron (puddled)		0.1375 0.083	
ead		0.03	
Lead		0.376	
Magnesium		0.01479	
Mercury		0.01279	
Mercury		0.01893	
Mercury Nickel		0.024	
		0.17	
Palladium Platinum		0.19	
Silver		1.096	
Steel (1 per cent. C.)		0.115	
Fin		0.113	
Fungsten		0.36	
Wood's metal (99.05 Bi + 0.95 Sn)		0.008	
Wood's metal (93.86 Bi $+$ 6.14 Sn)		0:012	
inc		0.303	
MUU		· · · · · · · ·	

Non-metals	Temperature, degrees C.	K	
Air	0	0.00057	
Cement		0.0001625	
Coal		0.000405	
Cotton (compressed)		0.00055	
Cotton wool		0.0004	
Felt		0.00009	
Flannel		0.000355	
Glass (crown)		0.00163	
Glass (flint)		0.00143	
		0.005	
Plaster of Paris		0.0013	
Paraffin		0.0006	
Quarts sand		0.00060	
Slate		0.00481	
Sulphuric acid		0.000765	
Water		0.001203	
		0.001203	
Water	40.8		
Wood (dry pine), dry walnut	0°-700°	0.0004	
Alumina brick		0.00204	
Asbestos paper		0.0006	
Cardboard		0.0005	
Coke powdered		0.00044	
Cork		0.00013	
Firebrick		0.00310	
Firebrick	0°-500°	0.00140	
Firebrick dust	20°-98°	0.00028	
Gas retort carbon, solid		0.0177	
Graphite		0.012	
Graphite-retort dust	20°-100°	0.00040	
Infusorial earth		0.00013	
Infusorial earth		0.00038	
Magnesia brick	0°-1300°	0.00620	
Magnesia-calcined Grecian granular	20°-100°	0.00045	
Magnesia-calcined light porous	20°-100°	0.00016	
Magnesite-brick dust	20°-100°	0.00050	
Mica (perpen. to cleavage)		0.018	
Paper		0.0003	
Rubber, Para		0.00045	
Sawdust		0.00012	
Slag wool		0.00012	
		A. MATA	

Table of Thermal Resistivities1

Approximately in Order of Resistivity (Temperature in Centigrade degrees)

	Th	ermal oh	ms ¹
	Inch cube	Centi- meter cube	Refer- ence
Silver, 0°-100°. Copper (electrode mean), 100°-197°. Copper (electrode mean), 100°-837°. Copper, 0°-100°, about. Copper. Copper, cast. Copper, rolled. Copper, rolled. Aluminum, 0°-100°. Graphite, Acheson (electrode mean), 100°-390°	0.094 0.090 0.11 0.11 0.13 0.12 0.11 0.13 0.27 0.28	0.24 0.23 0.27 0.27 0.32 0.29 0.28 0.32 0.69 0.71	LB HH LB CCJ WF LB H
Graphite, Acheson (electrode mean), 100°-390° Graphite, Acheson (electrode mean), 100°-914° Brass, 0°-100°	0.28 0.36 0.28 0.43 0.22 0.46 0.76	0.71 0.82 0.92 0.71 1.1 0.55 1.2	H LB H CJ LB
Iron, wrought. Iron, cast. Iron, cast, 30°. Steel. Steel, various.	0.79 0.26 0.63 0.24 0.81	2.0 0.66 1.6 0.60 2.1 2.1	WF CJ LB CJ WF LB
Steel, 10 per cent. manganese	3.0 0.25 0.55 1.1	7.7 0.63 1.4 2.9	LB CJ LB WF

¹ Hering uses an expression, the thermal ohm, which is the resistance through which 1 watt of heat flow will pass when the temperature drop is 1° C. Hence, if R is the thermal resistance in thermal ohms, W the flow of heat in watts and T the temperature in Centigrade degrees:

$$W = \frac{T}{R}$$

Or if r is the specific thermal resistance in thermal ohms per centimeter cube then

$$R = \frac{rL}{S}$$

where L is length and S is cross section.

To reduce a thermal conductivity in gram calories per second to resistivity in thermal ohms, multiply the reciprocal of the conductivity by 0.2388, when both are for 1 cm. To reduce gram calories to watts, multiply by 4.186. In order to compare thermal resistivities Mr. Hering called that of silver the unit, and reduced all values to this base.

To use the data of the table for all purposes it may be remembered that

watts \times 0.00134111 = horse power watts \times 0.0568776 = B.t.u. per minute.

	The	ermal ohi	ms¹
	Inch cube	Centi- meter cube	Refer- ence
Carbon (electrode mean) 100°-942°	0.72	1.9	H
Carbon (electrode mean) 100°-360° Lead	$\frac{1.05}{0.33}$	2.7 0.83	H CJ
Lead	$\begin{array}{c} 1.10 \\ 1.2 \end{array}$	2.8 3.0	LB
Lead, 0°-100°. Plumbago brick, about 1000°	3.8	9.6	WQ
Carborundum brick, about 1000	4.1	10.3	WQ
Mercury, 0°-50°	5.5 5.9	14.1 15.0	LB LB
Graphite (probably plumbago) 7°	8.0	21.0	LB
Retort carbon, 0°	$\begin{array}{c} 9.1 \\ 13.0 \end{array}$	23.0 34.0	LB WQ
Stone, calcareous, fine	16.0	42.0	P
Chromite brick, about 1000°	16.0	42.0	WQ
Marble, fine grained, gray	16.0 9.8	42.0 25.0	LB P
Marble, coarse grained, white	12.0	31.0	P
Marble, 30°	19.0	48.0	LB P
Stone, calcareous, ordinary	$\begin{array}{c} 20.0 \\ 21.0 \end{array}$	51.0 53.0	D
Firebrick, about 1000°	22.0	57.0	WQ
Firebrick, mean for 500°-1300°	$\begin{array}{c} 23.0 \\ 30.0 \end{array}$	57.0 77.0	Z
Firebrick, about 400°-800°	44.0	112.0	CE
Firebrick, mean for 0°-500°	67.0	171.0	Z
Checker brick, about 1000°	$\begin{array}{c} 24.0 \\ 25.0 \end{array}$	61.0	WQ WQ
Slate, 94°	26.0	67.0	LB
Building brick, about 1000°	$\begin{array}{c} 29.0 \\ 35.0 \end{array}$	72.0 89.0	WQ WQ
Glass pot, about 1000°	38.0	96.0	LB
Terracotta, about 1000°	41.0	104.0	WQ
Chalk, solid	43.0 44.0	109.0 110.0	LB N
Cement, Portland, 90°	132.0	336.0	LB
Lava Silica brick, about 1000°	47.0	120.0 120 0	LB WQ
Kieselguhr brick, about 1000°	47.0 52.0	133.0	wo
Red brick wall, average 8-in40-in. walls	62.0	160.0	W
Water, room temperature	72.0 87.0	180.0 220.0	LB LB
Plumbago, 20°-155°, 26.1 per cent. solid matter	96.0	240.0	0
Fine sand, 20°-155°, 51.4 per cent. solid matter	109.0	276.0	0 ·
Coarse sand, 20°-155°, 52.9 per cent. solid matter.	110.0	280.0	0
Cork. solid	131.0	333.0	LB
Plaster of Paris, 0°	105.0	266.0	· LB
matter	221.0	562.0	0
Slag concrete, 1 slag: 0.61 cement by weight, 50°	178.0	453.0	N
Pumice stone, 18.2 lb. per cu. ft., 50° Pumice stone	169.0 187.0	430.0 477.0	I N LB
Brick dust, sifted	204.0	518.0	P
Asbestos, 20°-155°, 34.2 per cent. solid matter	139.0	353.0	O N
Asbestos, 36 lb. per cu. ft., 600°	$166.0 \\ 221.0$	422.0 562.0	N
Asbestos with air cells	416.0	1016.0	S
Cardboard, below 0°	239.0	606.0	LB

	Thermal ohms ¹		
	Inch cube	Centi- meter cube	Refer- ence
Wool, sheep's, 8.5 lb. per cu. ft., 50°	676	1720	Ŋ
Wool, sheep's, 8.5 lb. per cu. ft., 100°	745 803	1890 2050	NC NB C
Mineral wool. 21°-175°	737	1870	B
Mineral wool, 0°-18°	1010	2570	C
Hard rubber	1060	2680	LB
Wood, pine, radially	1070	2720	LB
Loose fibrous materials, 9°	1540	3920	LB
Flannel	2650	6720	LB

Trans., Am. Soc. Mech. Eng., XVI, p. 827. B—George M. Brill.

Coverings on 8-in. steam pipes.

C-J. J. COLEMAN. Engineering, Sept. 5, 1884, p. 237. Ice melted in cube surrounded with the materials. Temperatures 0-18° and 0-38° C. The values were given relatively to each other; to reduce them to absolute measure it is here assumed that the value for sawdust is 620, thermal ohm, inch cube units.

CE—CLEMENT and EGY.

CJ—CALVERT and JOHNSON. Relative values based on silver. Reduced here on the basis that the conductivity of silver is 1.0 in gram calories per

second, centigrade, centimeter cube units.

D—Depretz, Hood. "Warming and Ventilating Buildings," p. 249.

Given relatively to marble, here assumed to be 10 thermal ohms, inch cube

H—Carl Hering. "The Proportions of Electrodes for Furnaces."
(Table.) Paper read before the Am. Inst. Elec. Eng., March 31, 1910.
Mean values when materials are used as furnace electrodes.
LB—Landolt and Boernstein tables. The values here chosen are mostly approximate means of the generally numerous and sometimes greatly differing values given by different observers. For the individual values and for the authorities see those tables. They also include values for

very many other materials.

N—WILHELM NUSSEL. Zeit. Ver. Deut. Eng., June, 1908, p. 906, table, p. 1006. Materials were placed between two concentric metallic spheres or cubes. Heat generated electrically in interior. Temperature measured cubes. heating. As here given they represent the resistivities at the temperatures stated, not the means over a range. Probably the best and most reliable determinations published. His conductivities are here assumed to be in terms of kilogram calories per hour, centigrade, meter cube, units; although not so stated directly in the original, it is undoubtedly what is meant. An abstract appeared in the Eng. Digest, August, 1908, p. 168, in which the units are reduced to thermal units, feet, inches and Fahrenheit degrees; the formula there given omits to say that it is necessary to multiply by the temperature also.

O-Prop. Ordway. Trans., Am. Soc. Mech. Eng., Vol. VI, 1884-5, p. 168. Tested in plates 1 in. thick between two flat iron surfaces, one of them heated by steam, the heat emitted by the other being measured calorimetrically. Extended, carefully made researches; presumably very good values. There is an error in the heading in Table VII; square inch should read square

meter, as in the others.
P—Pecler, Box. "Practical Treatise on Heat." Presumably ordinary

weather temperatures.
S—H.G. Storr. Power, 1902. Pipe coverings. 200 ft. of 2-in. pipe heated electrically to constant temperature. Coverings were somewhat over 1 in. thick; they are here reduced to 1 in. Heat transmitted to air, hence these resistances include that at the surface.

W-Wolff. Jour. Frank. Inst., 1893. The transmission of heat from the interior to the exterior of buildings through the walls; hence ordinary weather temperatures. Prescribed by law by German Government for heating plants. Said to agree well with good American practice. The value here given is an average of all the individual ones, omitting the first one, which differed greatly from all the others.

WF-WIEDEMANN and Franz; relative values based on silver. Reduced

here on the basis that the conductivity of silver is 1.0 in gram calories per second, centigrade, centimeter cube, units.

WQ—WOLOGDINE, QUENEAU. The temperatures were about 1000°C.; the materials were those of commerce and do not refer to extra pure or to inferior grades. The present writer is of the opinion, based on the method used in the tests, that these values are probably too low.

Z—Source lost, but probably fairly good values.

For further information the reader is referred to Metallurgical and Chemical Engineering, September, 1909, p. 383; February, 1909, p. 72; December, 1911, p. 652.

According to WILLIAM NUSSEL, thermal conductivity increases by 147.8

for each degree Centigrade rise in temperature.

THERMAL CONDUCTIVITY OF REFRACTORIES¹

Woodland firebrick	Quartsite (ganister and clay)	Star silica (ganister and lime)	Magnesite (dead burned)
SiO2	73.91 22.87 1.48 0.29 0.31 1.20	95.85 0.88 0.79 1.80 0.14 0.39	2.50 0.50 7.00 2.75 86.50
Density 1.91 K at 100°C 0.0043 K at 1000°C 0.0086	1.91 0.0051 0.0086	1.56 0.0056 0.0108	2.46 0.03431

Flow of Heat Inward from a Heated Plane Face³

Starting with the simple fundamental law for the flow of heat in the steady state—namely, that the amount of heat conducted varies directly as the conductivity, area, time and temperature difference, and inversely as the thickness—it is not particularly difficult to derive the solution for this case with the aid of Fourier's Series. For such derivation, however, the reader is referred to any treatise on heat conduction where he will find it given in the form:

$$T = T_0 \frac{2}{\sqrt{\pi}} \int_{-\frac{x}{2h\sqrt{t}}}^{\infty} e^{-\beta} d\beta$$

This means that for a body initially at the zero of our temperature scale, whose plane surface is suddenly heated to and maintained at T_0 , the temperature T at a distance x from this surface will be given t seconds later by this integral. As to the meaning of h, a little thought will serve to show that inasmuch as the temperature of the substance must be raised by the heat

¹ From a paper by Boyd Dudley, Jr., read at the Atlantic City meeting of the American Electrochemical Society, April, 1915.

² From 445° to 830°C. K is expressed in gram calories per second per inch cube per degree Centigrade, a peculiar unit.

³ Taken from an article by L. R. INGERSOLL in Eng. News, Oct. 30, 1913.

wave as it travels into the body, the rate of this penetration will depend not only on the conductivity, but on the specific heat and density of the material as well. This is taken account of in the constant h which is defined by the relation

$$h^2 = \frac{k}{c\rho}$$

k, c and ρ being respectively the conductivity, specific heat and density of the material. The quantities x, h and t being known, T can be determined. Tables I and II give the values of this integral, and of the constant h^2 , or thermal diffusivity.

Table I.—Values of Integral
$$E = \frac{2}{\sqrt{\pi}} \int_{\frac{x}{2h\sqrt{t}}}^{\infty} e^{-\beta t} d\beta$$

$x/2h\sqrt{t}$	E	$x/2h\sqrt{t}$	E	$x/2h\sqrt{t}$	E
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.25 0.30 0.35 0.40	1.000 0.987 0.955 0.932 0.910 0.888 0.865 0.843 0.821 0.800 0.777 0.724 0.671 0.621 0.572	0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00 1.10 1.20 1.30	0.525 0.480. 0.437 0.396 0.358 0.322 0.288 0.258 0.229 0.203 0.179 0.157 0.120 0.090 0.066	1.40 1.50 1.60 1.70 1.80 1.90 2.00 2.10 2.20 2.30 2.40 2.50 2.60 2.70	0.048 0.034 0.024 0.016 0.0109 0.0072 0.0047 0.0030 0.0019 0.0011 0.0007 0.0004 0.0002 0.0001 0.0000

Examples.—The use of these tables is best shown by solving some specific examples:

1. A massive granite block at 20°C. (68°F.) has one face (rapidly) heated to 200°C. (392°F.). What will be the tem-

perature at a depth of 10 cm. (4 in.) after 1 hour?
Since the theory is based on the assumption of an initial temperature of zero the temperature scale must be shifted in this case by subtracting 20°, which will be added again later. Taking h^2 from Table II as 0.0155, t as 3600 (seconds) and xas 10 (cm.), the quantity $x/2h\sqrt{t}$ becomes 0.67. This gives, from Table I, E=0.34; hence the rise in temperature would be

T=180E, or 61°, making a final temperature of 81°C. (178°F.). 2. The surface of a dry soil initially throughout at 6°C. (43°F.) is cooled to -20°C. (-4°F.). How long before waterpipes at a depth of 152 cm. (5 ft.) will be in danger of freezing?

Here we have, after shifting the temperature scale,

$$-6 = -26E$$
, or $E = 0.23$

From Table I, then, $x/2h\sqrt{t} = 0.85$, which, with $h^2 = 0.0031$, gives t = 2,600,000 seconds or 30 days.

Table II.—Values of Thermal Conductivity Constants in C. G. S.¹ Units²

Material	Tempera-	Con-	Dif-
	ture,	ductiv-	fusiv-
	deg. C.	ity, k	ity, h ²
Air Aluminum. Brass (yellow). Brick (firebrick). Brick (in masonry). Concrete (cinder). Concrete (stone). Copper. Cork (ground). Glass (ordinary). Granite. Iron (wrought or mild steel). Iron (cast, also high-carbon steel). Lead. Limestone. Magnesium carbonate (85 per cent. steam-pipe covering). Marble (white). Nickel. Rock material, average. Sandstone. Silver. Snow (fresh). Soil (average, damp). Soil (very dry). Water. Wood (dry pine—across grain). Wood (dry pine—with grain).	18 18 18	0.000055 0.480 0.204 0.0040 0.0020 0.00081 0.0022 0.918 0.00012 0.0024 0.0081 0.0052 0.1436 0.108 0.0827 0.0050 0.0050 1.006 0.0042 0.0042 0.0042 0.0050 1.006 0.0003 0.0003 0.0009 0.00030	0.179 0.826 0.339 0.0074 0.0050 0.0031 0.0058 1.133 0.0017 0.0057 0.0155 0.0112 0.173 0.121 0.237 0.0092 0.152 0.0118 0.0133 1.737 0.0033 0.0055 0.0031 0.00068 0.00068 0.0023

Flow of Heat Inward from Two Heated Faces

If a plate or slab of thickness l and initial temperature zero have both its faces suddenly heated to and kept at T_o , the temperature T in the middle plane, which will obviously be the last part of the body to heat up, may be obtained from the equation

$$T = T_o \left(1 - \frac{4}{\pi} 10^{-0.434} \frac{h^2 \pi^2 t}{l^2} + \frac{4}{3\pi} 10^{-0.434} \frac{9h^2 \pi^2 t}{l^2} - \dots \right)$$

t being the time in seconds and h^2 the thermal diffusivity. To

The use of this system is almost compulsory in cases where thermal diffusivity is involved, since it is the only one in common use which is consistent in its choice of fundamental units. Thus the steam engineer's conductivity unit of the B.t.u. per hour, per square foot, per degree F., per inch in thickness, is not available in this case since it involves two different units of length, i.e., the inch and foot. Similar objections may be raised against most of the other units in common use with the exception of the C. G. S.

Most of the values for metals are those of JÄGER and DIESSELHORST, Abh. d. phys-tech. Reichsanstalt, Vol. 3, p. 269 (1900). The others have been compiled from various sources. When not otherwise specified, ordinary

temperatures are assumed.

This table is also taken from INGERSOLL's article. Some of these constants differ from those given in the table on p. 146, but the differences are not serious, and since his diffusivity constants have been computed on this basis, it seems better to let the table stand as originally printed.

simplify computation, the values of this series have been tabulated as in Table 1II.

Table	III.—VALUES OF	THE	Function
$y=1-\frac{4}{\pi}\Big(10^{-z}-$	$\frac{1}{3}10^{-9s} + \frac{1}{5}10^{-25s} -$.) where $x = 0.434 \frac{h^2 \pi^2 t}{l^2}$

x	ν	$oldsymbol{x}$	ν	x	ν
0.01	0.0000	0.11	0.0546	0.36	0.444
0.02	0.0000	0.12	0.0692	0.38	0.469
0.03	0.0000	0.13	0.0848	0.40	0.493
0.035	0.0001	0.14	0.1009	0.45	0.548
0.04	0.0005	0.15	0.1176	0.50	0.597
0.045	0.0010	0.16	0.1345	0.60	0.680
0.05	0.0021	0.17	0.1517	0.70	0.74
0.055	0.0037	0.18	0.1690	0.80	0.79
0.06	0.0055	0.19	0.1862	0.90	0.839
0.065	0.0081	0.20	0.2033	1.00	0.872
0.07	0.0113	0.22	0.2372	1.25	0.92
0.075	0.0150	0.24	0.2702	1.50	0.959
0.08	0.0194	0.26	0.3022	1.75	0.97
0.085	0.0241	1.28	0.3331	2.00	0.98
0.09	9.0294	0.30	0.3727	2.50	0.99
0.095	0.0351	0.32	0.3912	3.00	0.998
0.10	0.0412	0.34	0.4184 .	3.50	0.999
				4.00	0.999

Examples.—A dry spruce cross-tie 11.4 × 17.8 cm. (4½ × 7 in.) in section and 71 cm. (28 in.) long, and at an initial temperature of 15°C. (59°F.), is placed in an oven which heats its surface to 137°C. (278°F.) for 10½ hours. What should be the temperature at the end of this period for a point near the center of the tie?

As the heat penetration will be largely due to conduction across the smallest dimension of the tie we shall neglect the other faces altogether. We have then, effectively, a plate of thickness 11.4 cm. and diffusivity 0.0068 (pine wood in Table II), which gives x = 0.85. Then from Table III, y = 0.82, making a rise in temperature of 0.82 ($137^{\circ} - 15^{\circ}$), or 100° . This gives a final temperature of 115° C. (239° F.). In an actual experiment this was found to be 113° C., checking our theory much more closely than could be expected, considering the approximations we have made in neglecting the other faces.

In the same way we can readily show by a few minutes' work with a slide-rule that the center of a plate of steel 2.54 cm. (1 in.) thick, which is plunged into molten lead, should rise to within 2 per cent. of the temperature of its faces in less than half a minute; the center of a firebrick 6.3 cm. (2½ in.) thick, heated by flue gases in a regenerator, should show more than half its surface change in temperature in 10 minutes, and more than three-quarters in 20 minutes; a disk of glass 20.3 cm. (8 in.) thick, which has been subjected to a recent heating or cooling of a dozen degrees should be kept with faces at constant tem-

perature for upwards of 10 hours to insure that the interior temperature is uniform to a small fraction of a degree.

Relative Conductivities of Metals for Heat and Electricity

The following table, compiled from various sources, is intended to show merely the general correspondence between conductivity for heat and for electricity. For ordinary work, the table of heat conductivities just preceding, and of electric resistivity just following, should be used. The electric conductivities are the reciprocals of the resistivities given in the later tables.

Metal (in vacuo)	Heat	Elec- tricity	Metal (in vacuo)	Heat	Elec- tricity
Silver	74 54.8 31.33 28.1	27.39 22.0	Iron	7.9 6.3 4.03	14.44 10.53 7.77 6.0

RELATION OF HEAT AND ELECTRIC CONDUCTIVITYS

Material	Thermal conductivity Electrical conductivity at 18°C.	Temperature coefficient of this ratio, per cent.
Copper, commercial Copper (1), pure	6.76×10^{10} 6.65×10^{10}	0.39
Copper (2), pure	6.71×10^{10}	0.39
Gold (1), pure	$\begin{array}{c} 6.86 \times 10^{10} \\ 7.27 \times 10^{10} \end{array}$	0.37 0.36
Gold (2), pure	7.09×10^{10}	0.37
NickelZinc (1)	$\begin{array}{c} 6.99 \times 10^{10} \\ 7.05 \times 10^{10} \end{array}$	0.39 0.38
Zinc (2), pure	6.72×10^{10}	0.38
Cadmium, pureLead, pure	$7.06 \times 10^{10} \ 7.15 \times 10^{10}$	0.37 0.40
Tin, pure	7.35×10^{10}	0.34
Aluminum	$\begin{array}{c} 6.36 \times 10^{10} \\ 7.76 \times 10^{10} \end{array}$	0.43
Platinum (2), pure	7.53×10^{10}	0.46
Palladium	$7.54 \times 10^{10} \\ 8.02 \times 10^{10}$	0.46 0.43
Iron (2)	8.03×10^{10}	0.44
SteelBismuth	9.03×10^{10} 9.64×10^{10}	0.35 0.15
Constantan (60 Cu, 40 Ni)	11.06×10^{10}	0.23
Manganin (84 Cu, 4 Ni, 12 Mn)	9.14×10^{10}	0.27

¹ Table used by Sir J. J. Thomson at a lecture before the Institute of Metals, May, 1915. Attributed by him to Jäger and Diesselhorst.

RESISTIVITY OF METALS (Microhms per cm.*)

	(1411610)	iims ber e	ui.~)		
	-160°	00	18°	100°	Temp. coeff. at 0°
Aluminum. Antimony. Bismuth. Cadmium (drawn). Copper (drawn). Cobalt. Gold. Arsenic. Iridium. Iron. Iron (wrought). Lead (drawn). Lithium. Magnesium. Mercury. Molybdenum. Steel. Nickel. Osmium. Palladium. Platinum. Potassium. Rhodium. Silver. Sodium. Strontium. Tantalum. Tellurium. Thallium. Thorium. Tin (drawn). Tungsten (annealed). Zinc.	2.72 0.49 	4.35 94.07 9.0 6.64 1.50 4.74	2.94 40.5 119.0 7.54 1.78 10.5 9.71 2.42 5.3 9-15 13.9 20.8 95.57 4.1 ² 19.9 11.8 9.5 ² 10.7 11.0 6.0 1.65 25.0 ² 14.6 21.0 ² 40.1 11.3 4.81 6.1	4.13 160.3 9.82 2.36 3.11 16.8 18.8 27.7 25.6 15.7 13.8 14.0 2.13 	0.0040 0.0041 0.0035 0.00426 0.0039 0.0037 0.0058 0.0058 0.0059 0.00506 0.00376 0.00377

 $^{^{1}}$ At -183° . ² At 25°. 3 At 20°. $4 \text{ At} - 204^{\circ}$. ⁵ From 18° to 100°.

The values at low temperatures are mostly Lee's; those at 18°, JAEGER and DIESELHORST'S; those at 0° from a table compiled by WATT'S, "Laboratory Course in Electrochemistry," while those at 100° are from various sources.

ALLOYS¹

	-160°	0°	18°	100°	Temp. coeff. at 0°
German silver ² Nichrome Brass	4.1	26.6 95.5	6.6	27.6	0.0003 0.00044 0.0010
Constantan	4		49.0	49.1	$ \begin{cases} -0.000050 \text{ to} \\ +0.000050 \end{cases} $
Manganin ³		1	43.50	42.1	0.00002 to 0.0000394
Phosphor bronze Woods alloy	• • • • • •		5-10 31.25		

¹ Temperature coefficients from "Standard Handbook."

² 62 per cent. Cu, 15 Ni, 22 Zn.

³ 84 per cent. Cu, 4 Ni, 12 Mn.

⁴ Most samples of manganin have a zero temperature coefficient from 30° to 40°C.

RESISTIVITIES AT HIGH TEMPERATURES¹ (Values in italics are merely exterpolated)

500°C.	Microhms,	1000°C.	Microhms.
932°F.	cm. cb.	1832°F.	cm. cb.
	<u> </u>		
Gilver eolid	5.0	Conner colid	9.42
Silver, solid	5.1	Copper, solid	12.54
Gold, solid.	6.62	Silver, fused	17.01
Aluminum, solid	10.0	Aluminum, fused	24.0
Brass, 2-1, solid	12.5	Molybdenum, solid	28.5
Molybdenum, solid	16.5	Tungsten (a), solid	30.5
Molybdenum, solid Tungsten (a, b), solid	18.0	Tungsten (b), solid Platinum (b), solid	33.4
Platinum (b), solid	25.3	Platinum (b), solid	40.8
Cadmium, fused	34.12	Brass, 2-1, fused	41.0
Platinum (a), solid	34.4	Tantalum, solid	57.0
Tantalum, solid	36.0	Platinum (a), solid	66.0
Zinc, fused	36.60	Tin, fused	68.0
Iron (a), solid, about	52.0	Lead-tin alloy, fused	98.0
Tin, fused	54.62	Ferronickel, solid	105.0
Lead-tin alloy, fused	81.0 94.0	Iron (a), solid, about	111.0
Ferronickel, solid	102.85	Calido, solid	122.0 125.0
Lead, fused	109.0	Lead, fused	128.0
Calido, solid	115.0	Antimony (b), fused	136.0
Nichrome II, solid	119.0	Bismuth, fused	167.5
Bismuth, fused	139.9	District, Adocu	Ohms
Antimony, solid	152.0	Graphite (b)	0.00065
	Ohms	Graphite (a)	0.00086
Graphite (b)		Carbon (d)	0.0021
Graphite (a)	0.00084	Carbon (a)	0.0024
Carbon (a)	0.0027	Carbon (c)	0.0030
Carbon (d)	0.0028	Carbon (b)	0.0034
Carbon (c)	0.0033	Carbon powder	0.12
Carbon (b)	0.0037	Silfrax B	0.84
Carbon powder	0.22	Sodium chloride, fused.	0.90
Silicon	0.094 to	Glass, roughly about	1.0
Tood allowed food	0.23	Graphite grains	1.7
Lead chloride, fused, 520°	0.418	Carbon grains (b)	1.9
Silver chloride, fused	0.547 0.824	Carbon grains (a)	2.8
Lead chloride, solid Silfrax B		Silicon powder	3:5 3.7
Copper chloride, fused	2.50	Kryptol	4.8
Graphite grains	2.70	Porcelain, about	15.0
Carbon grains (b), about	4.8	Manganese oxide pow-	10.0
Carbon grains (a), about	8.5	der	15.7
Kryptol	10.0	Copper oxide, CuO,	
Refrax	19.7	_powder	18.0
Boron, about	60.0	Zinc oxide powder	.26.7
Silicon powder	120.0	Iron oxide, Fe ₂ O ₈ ,	
Glass, about	330.0	powder	31.4
Iron oxide, Fe ₂ O ₈ , powder.		Quartz	110.0
Copper oxide, Cu2O, powder		Magnesium oxide pow-	
Manganese oxide, MnO ₂ ,	0000	der	1400.0
powder	2200.0	Alundum	8000.0
Copper oxide, CuO	เอติ40.0		l

¹ A table compiled by CARL HERING, "Metallurgical and Chemical Engineering," January, 1915.

1500°C.	Microhms,	1500°C.	Microhms,
2732°F.	cm. cb.	2732°F.	em. cb.
Silver, fused Copper, fused Aluminum, fused Gold, fused Molybdenum, solid Tungsten, solid Tungsten (b), solid Platinum (b), solid Tantalum, solid (b) Tantalum, solid (a) Tin, fused Platinum (a), solid Iron (a), solid, about Calido, solid Lead, fused	23.0 24.8 29.0 37.0 40.5 43.0 50.0 52.6 74.4 78.0 80.5 98.0 131.0 136.0	Iron (b), fused	166.0 Ohms 0.00058 0.00089 0.0016 0.0022 0.0029 0.5 0.7 0.85 1.2 3.4 750.0

Notes.—The resistivity depends to some extent on the state of the metal. In general, cold drawing increases while annealing diminishes the resistance. Winding a wire into a coil apparently increases its resistance. For pure metals the resistance is roughly proportional to the absolute temperature and would apparently vanish at absolute 0°. For alloys the rule does not hold even approximately. For pure metals the Brinnell hardness number is indirectly proportional to the electric

In "Engineering," Apr. 3, 1914, appeared a table of the relative resistances of metals in the liquid and solid states at

the melting point.

Metal resistance of liquid at melting point.

Sodium	1.35(a) $1.47(d)$	
Potassium	1.36(a) 1.54(d)	2.1(c) $2.12(g)$
Tin	2.2 (b) 2.21(e)	1.97(q)
Cadmium	1.8 (b) 1.96(e)	
Lead	1.9 (b) 1.95(e)	1
Thallium	2.00(e)	
Zinc		
Mercury		$ \ldots $ 1.5 (h)
Antimony	, , , , , ,	
Bismuth	0.46(b) 0.45(e)	0.46(q)

⁽a) A. Matthiessen. (b) L. de la Rivé.

(c) W. SIEMENS. (d) E. F. Northbup.

⁽e) G. VINCENTINI and D. OMODEI.
(f) P. CAILLETET and E. BOUTY.
(g) G. VASSURA.
(h) L. GRUNMACH.

VOLUME RESISTIVITY OF SOLID DIELECTRICS¹ (Materials arranged in order of decreasing resistivity)

Material	Resistivity, ohms-cm.	Material	Resistivity, ohms-cm.		
Special paraffinover	5000 × 1015	Black electrose	100×1012		
Ceresinover	5000 \$ 1018	Tetrachlornaphthalene			
Fused quartzover	5000 × 1018	Mica(India ruby stained)			
Hard rubber	1000 × 1018	German glass	50×1012		
Clear mica	200 × 1015	Paraffined mahogany	40×1012		
² Sulphur	100 × 1015	Stabalite	30 × 1012		
² Amberite	50×1018	Plate glass	20 × 1012		
² Rosin	50×1014	Hallowax No. 1001	20×10^{12}		
² Mica (India ruby slightly		Dielectrite	5×1012		
stained)	50×1018	Gummon	3×1012		
G. E. No. 55 R	40×1015	Tegit	2×1012		
Hallowax No. 5055 B	20×1018	Opal glass	1×1012		
Mica(brown African clear)			1		
Bakelite L558	20×1018	Paraffined poplar	500×10°		
² Electrose No. 8	20×1018	Paraffined maple	300×10°		
Selenium (in dark)	20×1018	Italian marble	100×10°		
² Parowax (paraffin)	10×1018	Bakelite micarta	50×10°		
Glyptol	10×1018	Black condensite	40×10°		
² Shellac	10×1015	Yellow condensite	40×10°		
Kavalier glass	8×1015	Vulcabeston	20×10°		
Insulate No. 2	8×1015	White celluloid	20×10°		
² Sealing wax	8×1015	Hard fiber	20×10°		
² Yellow electrose	5×1015	Black galalith	20×10°		
² Duranoid	3×1015	Lavite	20×10°		
² Murdock No. 100	3×1015	White galalith	10×10•		
² Yellow beeswax	2×1015	Hermit	10×10°		
Khotinsky cement	2×1015	Red fiber	5×10°		
Ebonite	2×1015	Marble, pink Tennessee.	5×10°		
Porcelain	2×1015	Gutta percha	2×10•		
² G. E. No. 55A	1×1015	Marble, blue Vermont	1×10•		
² Moulded mica	1×1015	_			
	1	Ivory	200×10°		
Unglazed porcelain		Slate	100×10 ⁶		
Redmonite (157.4)	1200×10^{12}	Bakelite No. 140	20×10 ⁴		

¹ From publications of U.S. Bureau of Standards.

² Apparent resistivity taken after the voltage had been applied for 15 minutes.

It should be noted that the superficial resistivity in moist air may be 10 to 100,000 times less than the internal resistivity, and that to a large extent it is the skin resistance that determines the usefulness of a conductor.

The following table of superficial and volume resistivities is taken from La Genie Civil, June 30, 1917, and is for a saturation of 90 per cent. moisture in the air surrounding the dielectric.

	Internal resistivity, ohms cm.	Superficial resis- tivity, air at 90 per cent. hum.
Bakelite No. 1	2×10^{11}	2×10^4
Bakelite No. 558	2 × 1014	9 × 10 ¹⁴
Celluloid	2 × 10 ¹⁰	1 × 104
Ebouite (new)	1 X 10 ¹¹	1 × 10
Fiber (red)	5 × 10°	2 × 104
Ivory	2×10^{4}	4 × 107
Marble—Italian	1 × 1010	2 × 10 ⁷
Tennessee.	5 × 10°	8 X 107
Vermont (blue)	1 X 10°	1 × 10 ⁷
Mica (clear)	2 × 10 ¹¹	5 × 10°
Micanite.	1 X 1011	+ r ·
Porcelain (enameled)	>5 × 10 ¹⁰ 2 × 10 ¹³	1 × 10 ¹⁷ 6 × 10°
Porcelain (not enameled)	3 × 10H	6 × 10 ⁷
Quarts (fused).	>5 2 104	2 × 104
Shellae	1 2 100	1 × 1014
Slate	1 2 10	i x io
Sulphur	î x îŏı	i 🗙 1014
Wood-acacia paraffined	4 × 1011	7 × 10°
-maple paraffined	8 × 1010	2 × 10*
—poplar paraffined	5 × 10**	2 × 10°

DIELECTRIC CONSTANTS COMPARED WITH AIR1

The inductivity, dielectric constant, or specific inductive capacity K of a material may be defined as the ratio of the capacity of a condenser with the material as dielectric to its capacity when the dielectric is dry air. That is, if two exactly similar condensers, except for the dielectrics, have one plate of each connected, the other plate earthed, then the distribution of charge on the two will be proportional to K.

Solida	Solids K		K		
Amber. Beeswax. Calcite. Ebonite. Fluorite	3.0 1.86 7.5-7.7 2.05-3.15 6.8	Silica, fused Spermaceti Sulphur Vaseline	3.5-3.6 2 2 2 2-3.9 2.17		
Glass, dint	5-7 7-9 6 8-10	Liquids	ĸ		
Gutta percha. Gypsum Ice (- 2°) India rubbec. Marble Mica Paper, dry Paper, impregnated Paraffin waz Pitch Porcelaiu Quarta Resin Rocksalt Rubber, vulcanized Selenium Shellac	2.1-2 3 8 3 4-8	Alcohol, methyl. Alcohol, ethyl Alcohol, amyl. Bromine Carbon disulphide. Carbon tetrachloride. Olive oil Kerosene Petroleum crude. Water. Gases vary from 0.9 to 1 0023 for carbon d Sulphur dioxide has a v at 15°C. and 760 mm. pr	26.8 at 14.7°C, 16.0 at 20°C, 3.1 2.62 2.25 at 18°C, 3.1.3.2 4.6-4.8 2.0-2.2 28 995 for helium isulphide vapor, alue of 1.00086		

¹ Compiled from various authorities

11

RESISTIVITY OF ELECTROLYTES (KOHLRAUSCH and HOLBORN)

Grams sub- stance in 100 g. of solution	Sp. gr.	Resistivity, ohms per cc. Temperature coefficient coefficient for 1°C. Gram equivaler per liter						
H ₂ SO ₄ at 18°C.								
1.0 2.5 5.0 10.0 15.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 85.0 90.0	1.0161 1.0331 1.0673 1.1036 1.1414 1.2207 1.3056 1.3984 1.5019 1.6146 1.7320 1.7827 1.8167 1.8368	21.93 9.24 4.82 2.57 1.85 1.54 1.36 1.48 1.86 2.70 4.67 9.13 10.30 9.38 9.84	0.00112 0.00115 0.00121 0.00128 0.00136 0.00145 0.00162 0.00178 0.00193 0.00213 0.00256 0.00349 0.00365 0.00320 0.00279	0.204 0.519 1.065 2.182 3.384 4.667 7.487 10.68 14.30 18.42 23.11 28.33 30.98 33.43 35.68				
97.0 99.4	1.8390 1.8354 118.00 12.50 118.00 10.00286 0.00400 37.22 HCl at 10°C.							
5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0	1.0242 1.0490 1.0744 1.1001 1.1262 1.1524 1.1775 1.2007	2.55 1.59 1.35 1.32 1.39 1.52 1.70 1.95	0.00159 0.00157 0.00156 0.00155 0.00154 0.00153 0.00152	1.408 2.884 4.431 6.050 7.741 9.506 11.33 13.22				
		KOH a	it 15°C.					
4.2 8.4 12.6 16.8 21.0 25.2 29.4 33.6 37.8 42.0	1.0382 1.0777 1.1177 1.1588 1.2088 1.2439 1.2908 1.3332 1.3803 1.4298	6.85 3.69 2.67 2.20 1.97 1.86 1.85 1.92 2.10 2.39	0.00188 0.00187 0.00189 0.00194 0.00200 0.00210 0.00222 0.00237 0.00258 0.00284	0.619 1.580 2.515 3.477 4.534 5.599 6.778 8.001 9.319 10.730				
		KCN at	: 15°C.					
3.25 6.5	1.0154 1.0316	19.10 9.80	0.00208 0.00194	0.508 1.031				

RESISTIVITY OF ELECTROLYTES. Continued

Grams sub- stance in 100 g. of solution	Sp. gr.	Resistivity, ohms per cc.	Temperature coefficient for 1°C.	Gram equivalents per liter		
		AgNO	at 18°C.			
5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0 45.0 50.0 55.0	1.0422 1.0893 1.1404 1.1958 1.2555 1.3213 1.3945 1.4773 1.5705 1.6745 1.7895 1.9158	39.47 21.20 14.78 11.57 9.53 8.14 7.17 6.45 5.88 5.44 5.09 4.80	0.00219 0.00218 0.00216 0.00213 0.00211 0.00210 0.00208 0.00206 0.00205 0.00206 0.00207 0.00210	0.307 0.642 1.009 1.410 1.851 2.338 2.879 3.485 4.168 4.940 5.800 6.780		
•		CuSO ₄	at 18°C.			
2.5 5.0 10.0 15.0 17.5	1.0246 1.0513 1.1073 1.1675 1.2003	92.4 53.2 31.4 23.8 21.9	0.00214 0.00217 0.00219 0.00232 0.00237	0.322 0.661 1.393 2.202 2.642		

RESISTIVITY OF ELECTROLYTES

Grams substance	Potassium chlor-	Sodium chloride resistivity, ohms per cc.	Calcium chloride
in 100 g. of	ide. resistivity,		resistivity,
solution	ohms per cc.		ohms per cc.
5 10 15 20 25	14.49 7.429 4.950 3.735	14.88 8.257 6.090 5.109 4.684	16.48 8.764 6.645 5.903 5.615
Grams substance	Cadmium chloride	Ammon. sulphate resistivity, ohms per cc.	Cadmium sul-
in 100 g. of	resistivity,		phate resistivity,
solution	ohms per cc.		ohms per cc.
5 10 20 30	41.49 37.59	18.11 9.901 5.677 4.363	68.5

RESISTIVITY OF ELECTROLYTES. Continued

Nitrie	acid	Sodium hydrate		
Grams HNO: per 100 cc. solution	Resistivity, ohms per cc.	Grams NaOH per 100 cc. sol.	Resistivity, ohms per cc.	
6.2 3.205		2.5 5.0	9.266	
12.4 18.6	1.845 5.0 1.449 10.0		5.076 3.205	
24.8	1.302	15.0	2.890	
31.0	1.023	20.0	3.058	
49.6 1.577		30.0	4.950	
6.2 2.016		40.0	8.621	

ELECTRIC RESISTANCE OF SOME METALLIC OXIDES¹
(Ohms per Cubic Centimeter)

Tem- perature deg. C.	Cr ₂ O ₃	Fe ₃ O ₄	SnO ₂	NiO	CaO	Al ₂ O ₃	SiO ₂	MgO	ZrO
	All of t	hese ha	ve a res	istance	of over	50,000	at room	tempe	atures.
400	6,000	11,750	900.0	3,000	1	1		 	
450	2,450		400.0	1,115	1	1		:	
500	1,250		235.0	490	1		. <i>.</i>		
550	1,000		125.0	400					
600	850	1,200		330			• • • • •	• • • • •	• • • • •
650	1,175	845	56.0	240]			
700	1,010	710	47.0	195	1	1			
750	950	510		121					
800	690	357		220					
850	668	290	•	280					
900	520	210	28.0	190					
950	395	162	25.5	81	l				
1,000	345	127	24.0	115					
1.050	335	117	23.0	93					
1.100	330	105		45					
Gas		2.50	32.20		}				- · · · · •
blow									
pipe					550	190	590	600	580

It is safe to say that where the temperature exceeds 1500°C. it is impossible to obtain even approximately good electrical insulation by any means whatever. (NORTHRUP.)

All metallic oxides are solids and have a lower specific gravity than have the metals. They melt at higher temperatures than do the metals.

¹ Zt. Electrochem., 1907, xiii, 589; as given in Hofman's "General Metallurgy."

Electrostatic Separation¹

LIST OF MINERALS

Good conductors

Poor conductors

Native metals **Pyrite Pyrrhotite** Chalcopyrite

Galena Garnet

Molybdenum

Copper glance or chalcocite Silver glance or argentite

Gray copper or tetrahedrite Most sulphides

Most copper minerals Most iron minerals Most silver minerals

Most manganese minerals

Tellurides Hornblende Black sands Quartz Quartzite Calcite

Limestone Porphyries

Slates

Sandstones

Garnet Spinel

Blende or sphalerite Smithsonite (ZnCO₂)

Barite Gypsum Granite Fluorspar Most silicates

Most gangue rocks

Monazite

THE ANNEALED COPPER STANDARD

Translation from the French text adopted at the International Electrical Commission, Berlin.

REPORT OF THE NATIONAL LABORATORIES CONCERNING AN INTERNATIONAL STANDARD FOR COPPER

I. Annealed Copper

The following values should be taken as normal for annealed

standard copper.

1. At 20°C., the resistance of an annealed copper wire 1 meter long and having a uniform cross-section of 1 sq. mm. is 1/58 $ohm = 0.017241 \dots ohm.$

2. At 20°C., the density of annealed copper is 8.89 grams per

cubic centimeter.

3. At 20°C., the coefficient of variation of resistance with temperature of annealed copper, measured between potential terminals rigidly attached to the wire (constant mass), is $0.00393 = \frac{1}{254.5}$ per deg. C.

4. Consequently, it follows from (1) and (2) that, at 20°C., the resistance of an annealed copper wire of uniform cross-section 1 meter long and having a mass of 1 gram is $(\frac{1}{58}) \times 8.89$, or

0.15328 . . . ohm.

II. Industrial Copper

1. The conductivity of annealed copper should be expressed at the temperature of 20°C. in percentage of that of standard annealed copper, and ordinarily to a precision of 0.1 per cent.

¹ R. H. RICHARDS, "Ore Dressing," Vol. III.

2. The percentage conductivity of annealed industrial copper should be computed in accordance with the following rules:

(a) The observation temperature should not differ from 20°C.

by more than 10°C.

(b) The resistance of a wire of industrial copper one meter long and of 1 sq. mm. cross section, increases 0.000068 ohm per deg. C.

(c) The resistance of a wire of industrial copper 1 meter

long and of 1 gram mass, increases 0.00060 ohm per deg. C.

(d) The density of industrial annealed copper at 20°C. should

be taken as 8.89 grams per cubic centimeter.

This value of the density should always be employed in the computation of conductivity in percentage of that of the

annealed copper standard.

It follows from the above that if R is the resistance in ohms, at t deg. C. of a wire having a length of l meters and a mass of m grams, the resistance of a wire of the same copper 1 meter long and 1 sq. mm. cross-section will be

$$Rm/(l^2 \times 8.89)$$
 ohms at t deg. C. and $Rm/(l^2 \times 8.89) + 0.000068(20 - t)$ ohms at 20°C. The percentage conductivity of this copper is thus

$$\frac{100 \times \frac{0.01724}{Rm}}{l^2 \times 8.89} + 0.000068 (20 - t)$$

Similarly, the resistance of a wire of the same copper 1 meter long and 1 gram in weight is

$$Rm/l^2$$
 ohms at t° C., and $Rm/l^2 + 0.00060(20 - t)$ ohms at 20° C.

The percentage conductivity is thus

$$100 \times \frac{0.1533}{\frac{Rm}{l^2} + 0.00060(20 - t)}$$

Note 1. The standard values given in (I) are mean values deduced from a large number of tests. Among a number of samples of copper of normal conductivity, the density may differ from normal density up to 0.5 per cent., and the temperature coefficient of resistivity may differ from the normal up to 1 per cent.; but between the limits indicated in (II) these deviations will not affect the values of the computed percentage conductivity, if the resulting values are limited to four significant digits.

NOTE 2. The values above stated correspond to the following physical constants for standard annealed copper, all at the temperature of 0°C.

Density, 8.90 grams per cubic centimeter.

Coefficient of linear expansion 0.000017 per deg. C.

Resistivity, 1.58791 microhm-cm.

Volume resistivity temperature-coefficient 0.004291 per deg. C. from and at 0°C.

Resistance temperature coefficient at constant mass, $0.00427 = \frac{1}{234.5}$ per deg. C. from and at 0° C.

Kelvin's Rule for Power Transmission

The most economical section of conductor is that for which the annual interest on capital outlay is equal to the annual cost for energy wasted.

COPPER WIRE TABLE

Solid wires are not made larger than No. 0000. A solid wire larger than a No. 3 is infrequently used, and the constants for wires larger than a No. 3 are given for stranded wires. Although wires are sometimes used as large as 2,000,000 circular mils, wires larger than 1,000,000 circular mils are not common, and are omitted from the table. The carrying capacities are those prescribed by the National Electrical Code.

Gage	Area in circular	Resistance in ohms per		capacity peres	Weight in pounds
number	mils	1000 ft. at 25°C.	Rubber insulation	Other insulation	per 1000 ft.
18	1,620	6.51	3	5	4.92
16	2,580	4.09	6	10	7.82
14	4,110	2.58	15	20	12.4
12	6,530	1.62	20	25	19.8
10	10,400	1.02	25	30	31.4
8	16,500	0.641	35	50	50.0
6	26,300	0.403	50	70	79.5
5	33,100	0.320	55	80	100.0
4	41,700	0.253	70	90	126.0
3	52,600	0.201	80	100	159.0
2	66,400	0.163	90	125	205.0
1	83,700	0.129	100	150	258.0
0	106,000	0.102	125	200	326.0
00	133,000	0.0811	150	225	411.0
000	168,000	0.0643	175	275	518.0
0000	212,000	0.0510	225	325	653.0
	250,000	0.0432	240	350	772.0
	300,000	0.0360	275	400	926.0
	400,000	0.0270	325	500	1,240.0
	500,000	0.0216	4 00	600	1,540.0
	600,000	0.0180	450	680	1,850.0
	700,000	0.0154	500	760	2,160.0
	800,000	0.0135	550	840	2,470.0
	900,000	0.0120	600	920	2,780.0
	1,000,000	0.0108	650	1,000	3,090.0

¹ These two numerical values will probably be changed to 1.5880 and 0.00428 by the National Physical Laboratories. Since reference is made exclusively to the values at 20°C. when measuring and stating percentage conductivity, these physical constants for 0°C. are of secondary importance in engineering.

PROPERTIES OF RESISTOR WIRES!

		Resistivit	Maximum	
Material	Composition	Microhm- cm.	Ohms, mil. ft.	Working temp., °C.
Copper	Annealed	1.724	10.37	260
German silver	Cu 58, Ni 18, Zn 24	33.3	200.0	260
Manganin			249.0-	100
	i	73.8	443.0	
Monel metal	Cu, Ni	42.6	256.0	480
Therlo	Cu, Mn, Al	46.7	280.0	200
German silver		48.2	-290.0	
Advance	Cu, Ni	48.8	294.0	370
[a Ia	Cu, Ni	49.0	295.0	
Raymur	Cu, Ni	49.0	295.0	
Constantin	Cu 60, Ni 40	50.0	300.0	1
<u> Pico</u>	Nickel steel	85.9	517.0	
Phenix	Nickel steel	87.0	524.0	540
Climax	Nickel steel	87.2	525.0	540
Calido	Ni - Cr	95.5	575.0	1090
Cophet	Ni - Cr	96.0	580.0	
Nichrome	Ni - Cr	99.6	600.0	900
Nichrome II	Ni - Cr	109.5	660.0	1100
Calorite	Ni - Cr	119.5	720.0	870

FUSING CURRENTS FOR COPPER WIRE

The following table has been tested for copper-wire fusing currents and was found to be closely correct for average conditions, according to the *Electrical Review*.

Size wire, B. & S.	Fusing current, ampere	Size wire, B. & S.	Fusing current, ampere
30	10	18	80
28	15	17	100
26	20	16	120
$\overline{25}$	25	15	140
24	30	14	160
$\overline{22}$	40	13	200
$\overline{21}$	50	12	240
$oldsymbol{ar{20}}$	60	11	280
19	70	10	330

If heat be developed in an electrical conductor faster than it can be dissipated from its surface by radiation and convection, the temperature will rise. The allowable rise in temperature is one of the limiting features of the current-carrying capacity of any conductor, since the rate at which heat will be dissipated will depend upon many conditions, such as the size and structure of the conductor, the kind and amount of insulation, if any, and the location with respect to other bodies. It is not possible to give any general definite rule for carrying capacity that will be true for all conditions.

¹ Standard Electrical Handbook.

The general subject of fusing currents for copper wire was investigated by W. H. Preece, who developed the formula: $I = ad^{\frac{3}{2}}$ where I is the fusing current in amperes, d is the diameter of the wire in inches, and a is a constant depending on the material. He found the following values for a.

Copper	7,585 5,172 5,230	Iron	1.642
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WIRE RESISTANCE TABLE¹

Gage No. B. & S.	Diam. in mils, 20°C.	Cross-section at 20°C., sq. in.	Copper ¹² ohms per 1000 ft.	Aluminum, sohms per 1000 ft.
0000	460.0	0.1662	0.04901	0.0804
00	364.8	0.1045	0.07793	0.128
1	289.3	0.06573	0.1239	0.203
2 4 6 8 10	257.6	0.05213	0.1563	0.256
4	204.3	0.03278	0.2485	0.408
6	162.0	0.02062	0.3951	0.648
. 8	128.5	0.01297	0.6282	1.03
10	101.9	0.008155	0.9989	1.64
12	80.81	0.005129	1.588	2.61
14	64.08	0.003225	2.525	4.14
16	50.82	0.002028	4.016	6.59
18	40.30	0.001276	6.385	10.5
20	31.96	0.0008023	10.15	16.7
22	25.35	0.0005046	16.14	26.5
24	20.10	0.0003173	25.67	42.1
26	15.94	0.0001996	40.81	67.0
$\overline{28}$	12.64	0.0001255	64.90	106.0
30	10.03	0.00007894	103.2	169.0
32	7.95	0.00004964	164.1	269.0
34	6.305	0.00003122	260.9	428.0
36	5.000	0.00001964	414.8	689.0
38	3.965	0.00001235	659.6	1080.0
40	3.145	0.000007766	1049.0	1720.0

Sparking Distances in Electrical Installations.—A mass of reliable data is now available concerning sparking distance between electrodes of simple geometrical form (needle points, disks, spheres, etc.), under various conditions, but little infor-

^{1 &}quot;Standard Electrical Handbook."

² Standard annealed, at 20°C. 3 Hard drawn, at 20°C.

mation has hitherto been available concerning sparking distances between metallic conductors and walls in workshops and on switchboards, etc. This problem, which is obviously of great practical importance was recently investigated by GINO REBORA (see also Atti dell' Associazione Elettrot. Italiana No. 31,913), and the first result deduced was the fact that a grain of dust or a fine hair or fiber would often suffice to start discharge from a high-tension conductor. A point or angularity in a conductor may cause a discharge to occur which would otherwise require 30 per cent. higher pressure than that actually operative; it is therefore very desirable that all metal subject to high-tension current should be as free as possible from points and angularities of any kind. The black lines frequently seen on switchboards and walls behind high-tension conductors reveal the presence of sustained feeble discharges which bombard the surface near the conductor with particles of dust.

From observations made in 30 installations, working at pressures between 3000 and 110,000 volts, Rebora derives a curve showing the minimum safe distance between conductor and earthed walls or metal covers, etc. As shown by the following data, his limits are rather less stringent than those recommended

(but not always observed) by the G. E. C.:

P. D.		20	40	60	80	100	Kilovolts
Minimum distance between conductor and earth	Rebora G. E. C.		200 300			1	Mm. Mm.

As regards the effective height of porcelain insulators of pylon form, used as intermediate insulators on distribution boards, etc., this height increases almost linearly at the rate of 5 or 5½ mm. per kilovolts for pressures up to 80 kv., and then increases more rapidly, to a total of 580 mm. for 100 kv. and 930 mm. for 130 kv. In deriving these data, Magrini, A. E. G., and Richard Ginori insulators were tested.

In the course of investigations conducted in the Ecole Polytechnique de Milan with a view to determining the laws of discharge between conductor and masonry, etc., copper wires, 2, 4, 5, 6 and 8 mm. in diameter, a bar 3 × 10 mm., and a brass tube 23/22 mm. in external and internal diameter were used. As second electrodes were employed in turn walls of cement, stone, hollow brick, eternite, and metal frameworks. The maximum testing pressure available was 100 kv. at 42 cycles per second. When the conductor under test was pointed straight at the wall, breakdown occurred at 20 per cent.—25 per cent. lower P. D. (for separations of 100 to 250 mm.) than would be required to produce discharge between needle points the same distance apart. This is a result of great practical importance, since live metal parts are frequently so arranged in high tension installations as to produce reductions in the factor of safety.

Thermoelectricity¹

When two different metals are brought into contact so that the two junctions are at different temperatures, there will usually be a slight current of electricity produced. The effective electromotive force is

volts =
$$\frac{(T_2 - T_1)[(B' - B'') + (C' - C'') \frac{T_2 + T_1}{2})]}{100,000,000}$$

where T_2 and T_1 are the temperatures of the junctions, and B and C constants as given in the following table:

Metal ·	В	C	Metal	В	C
Iren. Steel Soft platinum Hard platinum Magnesium German silver Zinc.	$+1139 \\ + 61 \\ + 260 \\ + 244 \\ + 1207$	$ \begin{array}{r} -1.10 \\ -0.75 \\ -0.95 \\ -5.12 \end{array} $	Silver	+283 +136 0 - 43 - 77	

The behavior of nickel is anomalous. Antimony and bismuth produce the greatest current of any two metals, but here again, the constants vary greatly according to the absolute temperatures of the junctions. See also p. 308.

PENETRATING POWER OF X-RAYS²

Substance	Specific gravity	Trans- parency	Substance	Specific gravity	Trans- parency
WaterAluminumGlassTinZincIronNickel	1.00 2.67 2.70 7.29 7.16 7.78 8.51	1.000 0.380 0.340 0.118 0.116 0.101 0.095	Copper Silver Lead Mercury Gold Platinum	8.92 10.24 11.39 13.59 19.63 21.53	0.084 0.070 0.055 0.044 0.030 0.020

Specific Gravity Tables

The following tables give the average specific gravities of most solids and liquids of importance in mining and metallurgy. There are separate tables for water, mercury, gases and the most important minerals.

Comparison of Standards.—Hydrogen, air and water are the three standards commonly used in the determination of the specific gravity of gases, liquids and solids. The relative densities of these standards are as follows:

Air (dry) is 14.418 times as heavy as hydrogen, at the same

temperature and pressure, volume for volume.

Water (max. density, 4°C.) is 773 times as heavy as dry air at 30°F., bar. 29.92 in.; and 815 times as heavy as dry air at 60°F., bar. 30 in., volume for volume.

¹ "Encyclopedia Americana," Vol. XV, "Thermoelectricity."

² The wave length of X-rays is apparently about 10⁻⁸ to 10⁻⁸ cm.

table is from the General Electric Review.

SPECIFIC GRAVITIES AND UNIT WEIGHTS OF SOLIDS AND LIQUIDS

Substance	Average sp. gr. (water = 1)	Average weight (lb. per cu. ft.
Alcohol, pure at 20°	0.789	49.2
commercial	0.834	52.1
Aluminum (cast)	2.56-2.71	164.0
(rolled)	2.66	166.0
Antimony	6.71	419.0
Argon (liquid, — 185°)	1.4	87.3
Arsenic (amorphous)	5.71	356.0
(crystallized)	5.73	358.0
(molten)	5.71	356.0
Asbestos	3.2	200.0
Ashes (packed)	0.72	45.0
Asphalt (1 to 1.8)	1.4	87.0
Barium		236.0
Beryllium	1.93	120.0
Bismuth (com'l)	9.74-9.92	614.0
(distilled)	9.78	611.0
(molten)	10.04	627.0
Boron	2.45	153.0
Brass, cast (7.8 to 8.4) 70 Cu, 30 Zn	8.1	506.0
rolled, 70 Cu, 30 Zn	8.4	524.0
Brick (fire)		140-150
(soft)	••••••	100.0
Brickwork, masonry (1.8 to 2.3)		110-140
Bromine (at 0°C.)	3.187	199.0
Bronse (8.7 to 8.9)		550.0
Cadmium		540.0
(molten)	7.99 1.87	499.0 117.0
Calcium		115.0
Carbon disulphide		80.5
Celluloid	1.4	87.4
(American, loose)	1.7	50 -6 0
Cerium		417.0
Chalk		156.0
Charcoal		13.0
Chromium		414.0
Clay (1.8 to 2.6)	1 2.2	137.3
Coal, anthracite (1.3 to 1.7)	1.5	93.6
bituminous (1.2 to 1.5)	1.3	81.15
cannel, gas coal (1.18 to 1.28)		76.78
lignite, brown coal		_68.67
Cobalt		540.0
Coke, loose piled		20-30
Concrete	2.3	144.0
Copper, cast (8.6 to 8.8)	8.7	543.0
deposited	8.92	557.0
molten		513.0
_ rolled (8.8 to 8.95)		556.0 14.98
Cork		
Diamond	3.52	76–95
Earth, loose to well rammed		105-115
wet, flowing mud	4.0	250.0
Emery		310.0
Erbium		45.9
Ethyl ether	1	370.0
Gallium		335.0
Germanium		527.5
LICETO ON CHIMP		,

From KAYE and LABY's "Physical and Chemical Constants." The figure appears high.

SPECIFIC GRAVITIES AND UNIT WEIGHTS OF SOLIDS AND LIQUIDS

Substance	Average sp. gr. (water = 1)	Average weight (lb. per cu. ft.
Glass	2.52	157.0
(heavy flint)	2.93	200.0
	1.26	88.7
Gold (19.25 to 19.37) (20 Karat = 16.47) (distilled)	19.31 19.27	1203.0
Granite (2.56 to 2.88)	2.72	170.0
Graphite (average value)	2.2^{-}	137.0
Gravel, loose		95-120
Greenstone (trap)	• • • • • • • • • • • • • • • • • • • •	170-200
Gypsum, ground or calcined, loosewell shaken	••••••	56.0 64.0
uncalcined		130-150
Hornblende		200-220
Ice	0.92	57.5
Iodine		309.0
Indium		444.0 1400.0
Iridium		450.0
(molten)		429.0
rolled	7.68	480.0
wrought, sheet (7.6 to 7.9)	7.8	485.0
vory	1.83-1.92	
Lanthanum	6.15	384.0
(molten)	10.64	664.0 75.0
Lime (quicklime)	1.5	93.75
ground, loose (66 lb. per bushel)		53.0
Limestone	2.7	168.0
Lithium	0.59	36.8
Loam	1.74	65-100 109.0
Manganese	7.392	461.0
Marble (2.5 to 2.8)	2.65	160-180
Marl		100-140
Mercury ¹ (32°F.)	13.5955	850.0
(62°F'.) solid, - 40°F.	13.555 15.632	847.0
Mica	$\begin{array}{c} 15.032 \\ 2.8 \end{array}$	976.0 175.0
Molybdenum	8.60	537.0
Mortar	•••••	90-105
Neodymium	6.956	434.0
Niokel	$\begin{bmatrix} 8.86 \\ 12.7 \end{bmatrix}$	553.0 793.0
NiobiumOils (0.910 to 0.975), weight given in pounds	12.1	783.0
per gallon:		
Animal, lard	0.916	7.64
sperm (pure)	0.880	7.34
whale	0.925	7.72
Mineral, petroleum (crude)	0.77-1.06 0.700	5.84
kerosene (coal oil)	0.800	6.68
naphtha	0.730	6.09
Vegetable, cottonseed	0.923	7.70
linseed (boiled)	0.933	7.79
(raw)	0.780	6.51 7.65
oliverape (colza)	0.917 0.915	7.63 7.63
まめ少で (501をみ)	0.010	1

¹ See also special table on p. 176. ² Given as 8.30 by Nystrom.

Specific Gravities and Unit Weights of Solids and Liquids

	Average	Average
Substance	sp. gr.	weight
	(water = 1)	(lb. per cu. ft.)
Osmium	22.48	1403.0
Palladium	11.90	743.0
Peat (dry, unpressed)	• • • • • • • • • • •	20-30
Phosphorus (red)	2.34	146.0
(white)	1.837	115.0
Pitch	1.155	72.0
Platinum wire	21.5	1342.0
Potassium	0.875 6.475	54.9 404.0
Præseodymium		50-60
Quartz		165.0
(broken)		94.0
Rhodium		787.0
Rosin	1.1	68.67
Rubber, hard (pure)	1,12-1,25	
Rubber, hard (commercial)	1.25 - 1.40	
Salt		45.0
Samarium	7.75	484.0
Sand (dry)		100.0
(wet)		130.0
Sandstone (2.1 to 2.7)	2.4 4.8	150.0
Selenium (gray metal)(red)	4.47	293.0 279.0
Shale (2.4 to 2.8)	2.6	162.0
Silicon (amorphous)	2.00	125.0
(crystallized)	2.195	137.0
Silver (cast)	10.75	671.0
(electrolytically deposited)	10.53	655.0
(molten)	9.51	594.0
Slate (2.7 to 2.9)	2.7	169.0 5-12
Snow (fresh, dry)	• • • • • • • • • • • • •	15-50
Soapstone	• • • • • • • • • • • •	166.0
Soda ash,	1.2	74.0
Sodium	0.972	60.7
Steel (7.69 to 7.93)1	7.85	490.0
Strontium	2.54	159.0
Sugar	1.6	
Sulphur	1.96-2.07 0.94	125.0 58.7
Tallow	16.6	1036. 0
Tar	1.0	62.5
Tellurium	6.25	390.0
Thallium	11.85	740.0
Thorium	12.16	759.0
Tin (cast)	7.29	459.0
(molten)	7.02	438.0
Titanium	4.87	304.0
TraprockTungsten	3.0 19.3–20.2	187.0 1248.0
Uranium	18.69	1667.0
Vanadium	5.50	337.0
Water ² (max. density 4°C.)	1.0	62.428
(pure. 62°F.)	0.999	62.366
(pure, 212°F.)	0.958	59.80 0
ses, average	1.028	64.176
Wax (bees),	0.97	60.5
1 Pure and soft The energific gravity deeper	4ba	ban increases

Pure and soft. The specific gravity decreases as the carbon increases.

See special table on p. 175 for water.

Given in Horman's "General Metallurgy" as 5.30.

Note.—Most of the constants for the chemical elements are taken from the "Annuaire pour 1915 der Bureau des Longitudes," omitting the last figure.

For the specific gravities of the metals, there are usually two values given. The low figures are usually those of cast metals, the high ones of metal either finely rolled or drawn into fine wire.

Substance	Average sp. gr. (water = 1)	Average weight (lb. per cu. ft.)	
Wood, dry, seasoned:			
Ash, white	0.6-0.8	38.0	
Birch		41.0	
Cedar, white		23.0	
red	• • • • • • • • • • • •	35.0	
Cherry		42.0	
Chestnut	.	41.0	
Elm	•	35.0	
Ebony		76.0	
Fir, Douglas	[20.0	
Hemlock		25.0	
Hickory		53.0	
Mahogany, Spanish		53.0	
		35.0	
Maple		49.0	
Oak, live		59.0	
white	0.8	48.0	
black, jack, etc		35-45	
Pine, white		25.0	
yellow, Northern	0.52	34.0	
Southern		45.0	
Poplar (cottonwood)		33.0	
		25.0	
Spruce		37.0	
		37.0 37.0	
Walnut	3.8	237.0	
Yttrium	3.8 7.15		
Zine		446.0	
(molten)	6.48	405.0	
Zirconium	6.25	390.0	

DENSITIES OF WATER AT DIFFERENT TEMPERATURES¹

1	1			
0.999868	15	0.999126	29	0.995971
0.999927	16	0.998970	30	0.995673
0.999968	17	0.998801	31	0.995367
0.999992	18	0.998622	40	0.99224
1.000000	19	0.998432	50	0.98807
0.999992	20	0.998230	60	0.98324
0.999968	21	0.998019	70	0.97781
0.999929	22	0.997797	80	0.97183
0.999876	23	0.997565	90	0.96534
0.999808	24	0.997323	100	0.95838
0.999727	25	0.997071	110	0.951
0.999632	26	0.996810	150	0.917
0.999525	27	0.996539	200	0.863
0.999404	28	0.996259	250	0.79
0.999271			300	0.70
	0.999927 0.999968 0.999992 1.000000 0.999992 0.999968 0.999929 0.999876 0.999808 0.999727 0.999632 0.999525 0.999404	0.999927 16 0.999968 17 0.999992 18 1.000000 19 0.999992 20 0.999968 21 0.999929 22 0.999876 23 0.999808 24 0.999632 26 0.999525 27 0.999404 28	0.999927 16 0.998970 0.999968 17 0.998801 0.999992 18 0.998622 1.000000 19 0.998432 0.999992 20 0.998230 0.999968 21 0.998019 0.999929 22 0.997797 0.999876 23 0.997565 0.999808 24 0.997323 0.999632 26 0.996810 0.999525 27 0.996539 0.999404 28 0.996259	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$

¹ The above tables are founded on Thiessen's figures as given in "Annuaire pour 1914, Bureau des Longitudes." Other authorities give values somewhat under his.

PROPERTIES OF WATER¹

Tempera- ture, deg. F.	Weight in pounds per cubic foot	Relative volume	Tempera- ture, deg. F.	Weight in pounds per cubic foot	Relative volume
32.0	62.418	1.00011	100	62.02	1.00686
39.1	62.425	1.00000	120	61.74	1.01138
50.0	62.41	1.00025	140	61.37	1.01678
60.0	62.37	1.00092	160	60.98	1.02306
62.0	62.355	1.00110	180	6 0.55	1.03023
70.0	62.31	1.00197	200	60.07	1.03819
80.0	62.23	-1.00332	210	59.82	1.04246
90.0	62.13	1.00496	212	59.76	1.04332

For sea water, multiply the above by 1.026. One U. S. gallon of water at 62°F. weighs 8.3356 lb. Water freezes at 32°F.; is at its maximum density at 39.1°F., British standard for sp. gr., 62°F.; boiling point at sea-level, 212°F.

1 From Pierce and Carver's "Formulas and Tables for Engineers."

PAYNE'S TABLE FOR WATER IN AIR1

The following table will give the amount of water weighed in air with brass weights necessary to fill a liter flask to the 1000 cc. mark at 20°C.

Temperature of water	Apparent weight	Temperature of water	Apparent weight
15	998.0	24	996.6
16	997.9	25	996.3
17	997.7	26	996.1
18	997.6	27	995.9
19	997.5	28	995.6
20 (standard)	997.3	29	995.4
21	997.1	$\bar{30}$	995.1
22	996.9	31	994.9
23	996.8	$3\bar{2}$	994.5

¹ Foulk's "Manual of Qualitative Analysis."

DENSITIES OF MERCURY¹

Tempera- ture deg. F.	Pounds per cubic inch		Pounds per cubic inch		Pounds per cubic inch
0 10 20 30 32	0.4928 0.4923 0.4918 0.4913 0.4912	40.0 50.0 58.1 60.0 70.0	0.4907 0.4903 0.4899 0.4898	80 90 100 110	0.4888 0.4883 0.4878 0.4873

Tempera- ture deg. C.	Grams per	Tempera- ture deg. C.	Grams per	Tempera- ture deg. C.	Grams per
-20 -10 0 10 20 30	13.6450 13.6202 13.5955 13.5708 13.5462 13.5217	40 50 60 70 80 90	13.4973 13.4729 13.4486 13.4243 13.4001 13.3759	100 150 200 250 300	13.3518 13.233 13.068 12.998 12.881

¹ ELLENWOOD's "Steam Charts."

KIRBY'S TABLE OF WEIGHTS OF ORE IN PLACE1

•	Weight per cubic foot		Cubic feet per ton	
Material	Theoret- ically,2 pounds	Practically, pounds	Theoret-ically ²	Prac- tically
Galena	465	426	4.3	4.7
Pyrite	313	286	6.4	7.0
Blende	250	235	8.0	8.5
Hematite	303	267	6.6	7.5
Limonite	238	213	8.4	9.4
Dolomite	175	160	11.4	12.5
Limestone, andesite, syenite	168	154	11.9	13.0
Vein quarts, granite and granitic	100	104	**.6	10.0
rocks	168	148	11.9	13.5
rhyolites	163	136	12.3	14.5
Vein quarts, with 15 per cent. galena.		164	10.7	12.2
Vein quarts, with 15 per cent. galena.	180	160	ii.i	$\frac{12.2}{12.5}$
Vein quarts, with 10 per cent. hema-	100	100	11.1	12.0
tite	170	155	11.4	12.9

McDonald's Table of Weights of Ore1

Material	Weight per cubic foot		Cubic feet per ton	
	In place, pounds	Broken, pounds	In place	Broken
Granite and porphyry	170	97	11.8	20.6
Gneiss	168	96	11.9	20.8
Greenstone and trap	187	107	10.7	18.7
Limestone	168	96	11.9	20.8
Slate	175	95	11.4	21.1
Quartz		94	12.1	21.3
Sandstone		86	13.2	23.3
Earth in bank			18.0	
Earth dry and loose		74	20.0	27.0
Clay	118		17.0	
Sand	80		25.0	

¹ Probably for ore as delivered to mill.

WEIGHT OF ROCK AND SAND1

	Cubic feet per ton	Weight in pounds per cubic foot
Sulphide ore in place	11 to 13	154 to 182
Sulphide ore broken	15 to 18	111 to 133
Oxidized ore in place	14 to 18	111 to 143
Exidized ore broken	22 to 24	81 to 91
Quarts in place (sp. gr. = 2.65)	12.0	165.0
uartz broken		94.0
arth in bank	18.0	111.0
arth, dry and loose	27.0	74.0
Jay,	17.ŏ	118.0
oose sand		80.0
Mill tailing ² (sp. gr. 2.7)		
Sand collected under water	21.5	93.0
Transferred sand (before leaching)		77.0
Leached sand (after transferring)		83.3

¹ From MacFarren's "Cyanide Practice." "Mining and Scientific Press,"

San Francisco, Calif.

2 W. A. CALDECOTT, Journ. Chem., Met. and Min. Soc. of S. A., Oct., 1910.

¹ R. H. Richards, "Ore Dressing, Vol. II."

² Calculated from specific gravity of pure unaltered specimens.

178 METALLURGISTS AND CHEMISTS' HANDBOOK

DENSITY AND HARDNESS OF MATERIALS1

	Specific	Hardness
Acide and oxides:	gravity	2100 (2004)
Arsenious seid, AsiOz	3.69-3.70	1.5
Boric acid, B(OH) ₂ Titanic acid, anatase, TiO ₂	1.48	1.0 5.5-6.0
brookite, TiOz	4.14	5.5-6.0
rutile, TiO ₂	4.28 2 63-2.80	6.0-6.5
Corundum, Al ₂ O ₄ .	3.90-4.02	9.0
Caprite, CurO	5.99	3.75
Diaspore, Al(OH): Al ₂ O ₃	3.37 6.30-7.10	6.5 6.5
Melaconite (black copper), CuO	6 20-6.30	3.0-4.0
Hematite, Fe ₂ O ₂	4.54-5.28 4.94-5.18	6.0 5.5
Ferric oxide (hydrated) limonite	3.60 - 4.00	5.8
Ice at 0°C	0 92 8.67	6.6
Magnesia (hydrated, brucite), Mg(OH)1	2.35	2.5
Manganese oxide, braunite,	4 75 4.72	6.0-6.5 5.0-5.5
pyrolueite, MnO2	4.82 - 4.97	2.0
Silica, agate, SiO1		6.0 7.0
Quarts, SiO ₁	2.65 2.03-2.09	5.5-6.5
Uranium oxide (pitchblende)	6.01-8.07	5.5 4.0-4.5
Zincite, ZnO	5.57	4.0-1.5
Spinel, MgO-Al ₂ O ₂	8.55	8.0
Anorthite, CanAlaSiaOns	2.7	6.0-7.0
Antimonides; Breithauptite, NiSb	7.54	5.5
Antimonite, SbySt	4.57	2.5
Arzenidea:		
Cobalt arsenide, smaltite, (Co, Ni) As;	6.41 7.75	3.0-3.5
Nickel arsenide, niccolite, NlAs	7.72	5 5
Boracite, MgrCl ₂ B ₁₆ O ₂₀	2 01-2 07	5.0-7.0
Borax, Na ₂ B ₄ O ₇ ·10H ₂ O	1.72	2.0
Bromides:		
Silver bromide, AgBr	8.80-6.00	2.0-3.0
Carbonates: Aragonite, CaCOs.		3.5-4.0
Azurite, 3CurCiOr7HiO	3.70-8 83	4 0
Calcite, CaCOs Corussite, PbCOs		3.0-3.65 3 25
Dolomite, MgCa(CO ₁):	2.83-2.94	3.75
Malachite, Cu ₂ CO ₄ H ₂ O		3 5 3.5-4.5
Siderite, FeCO ₁	3,83-3,88	3.5-4.0
Smithsonite, ZnCO ₁ Stromanite, SrCO ₄	4 30-4.45 3 60-3 71	5.0 3 5-4 0
Witherste, BaCO1	4 28	3.5
Chlorides:	9 70	2000
Atacamite, Cu ₂ (OH ₂)Cl	3.70 5.48	3.0-3.5 1.0-2.0
Calomel, HggClg. Carnallite, KMgClgGHgO	1.6	1.0
Cerargyrite, AgCl		1.5 2.5
Sylvite, KCl	1.90-2.00	2.0
Chromates:	1 00 6 10	
Lead chromate, PbCrO ₄ Chromite, FeCrrO ₄	4.32-4.50	2.5-8.0 5.6
⁴ From "Annuaire pour 1914, par le Bureau des		- -

•	Specific gravity	Hardness
Fluorides: Cryolite, Na:AlFe	2.96 3.14-3.19	2.5 4.0
Molybdates: Wulfenite, PbMoO4		3.0
Niobates and Tantalates: Fergusonite, Y, Er, Ce, Nb, Ts, O	5.84	5.5-6.0
Niobite, FeNb ₂ O ₆	5.60-6.00 5.54 7.03	5.0-6.0 6.0
Tantalite, FeTa ₂ O ₆		2.0
Saltpeter, KNO ₃	•	•
Apatite	2.90-3.20 3.57	5.0 2.0-2.5
Monazite (Ce, La)PO ₄ Pyromorphite, Pb ₄ Cl(PO ₄) ₃	5.00-5.09 6.59-7.05	$\begin{matrix} 5.2 \\ 3.5 - 4.0 \end{matrix}$
Turquoise	2.52-2.80 3.40-3.60	$\substack{\textbf{6.0}\\\textbf{2.0-2.5}}$
Silicates: Albite	2.60-2.62	6.0
Amphibole	2.92-3.59 3.14-3.16	5.5 7.5
Augite Emerald (beryl)	3.20-3.50 2.67-2.75	5.0-6.0 7.5-8.0
Epidote	3.46 2.50-2.59	6.5
albiteoligoclase	2.60-2.62 2.61-2.64	6.0 6.0
andesitelabradorite	2.67-2.68 2.70-2.72	6.0
anorthite	2.75 4.23-4.33	6.5-7.0
Granite	3.42 - 4.20	5.0-6.0
Hypersthene (Fe, Mg)SiO:	3.36-3.42 3.29-3.43	5.0-6.0 6.5
Jadeite, NaAl(SiO ₃) ₂	3.28-3.35 2.50-3.04	6.5-7.0 5.0-5.5
Peridote	3.33-3.41	6.5-7.0 7.5-8.0
Olivine (Mg,Fe) ₂ SiO ₄	3.30-3.50 2.70-3.10	6.0-7.0 2.0-2.5
Pyroxene, diopsideaugite	3.32 3.30	4.0-6.0 5.5
hedenbergiteQuartz, SiO ₂	3.50 2.65	7.0
Rhodonite	3.64 2.6	5.5-6.5 3.0-4.0
Sillimanite, Al ₂ OSiO ₄	3.24 4.19-5.22	7.5 4.5-5.0
Willemite, Zn ₂ SiO ₄	4.01	5.0 4.5-5.0
Zircon, ZrSiO4	4.04-4.67	7.5
Hydrated silicates: Calamine, Zn ₂ (OH) ₂ SiO ₂		5.0
Chrysocolla, CuSiO ₂ ·2H ₂ O	1.92 - 2.12	3.5
Kaolin	$\begin{array}{c} 2.5 \\ 1.80 - 2.20 \end{array}$	2.0 - 2.5
Pyrophyllite, HAl(SiO ₂) ₂	2.78 2.71	1.5 1.0
Thomsonite	2.38	5.0-5.5
Tourmaline	3.04-3.20	7.0-7.5

	Specific gravity	Hardness
Silicochloride: Pyrosmalite Sodalite		4.0-4.5 5.5-6.0
Silico-fluorides: Leucophane	2.97	4.0 2.0–3.0
Topaz Siliconiobate: Wöhlerite	3.51-3.58	8.0 5.5-6.0
Sulphates: Anglesite, PbSO4	6.26-6.30	3.0 3.0–3.5
Barite, BaSO ₄	4.48-4.72 3.92-3.96 1.75	3.0 3.0–3.5 2.0–2.5
Glauberite, Na ₂ SO ₄	2.64-2.85 2.33	2.0 2.5
Sulphides: Argentite, Ag2S Bismuthinite, Bi2Ss	6.40	2.5 2.0
Blende (sphalerite), ZnS	5.78	3.5-4.0 3.0 2.75 $4.0-4.2$
Chalcopyrite, CuFeS ₂	$8.12 - 8.20 \\ 5.05$	$\begin{array}{c} 2.0 - 4.2 \\ 2.5 \\ 3.0 \\ 2.75 \end{array}$
Greenockite, CdS	4.99	3.0-3.5 6.0-6.5 3.5
Molybdenite, MoS ₂	4.94 3.45 4.85-5.04	1.5 1.75 6.0
Pyrrhotite, FeS	4.62 3.64 4.62 4.09	$egin{array}{c} 4.0 \\ 2.0 \\ 2.0 \\ 3.5-4.0 \end{array}$
Sulph-antimonides: Bournonite, PbCuSbS:	5.75-5.83	2.5-3.0 2.5
Pyrargyrite, Ag ₃ SbS ₃	5.86 6.26-6.37	2.5 5.5
Enargite, Cu ₂ AsS ₄	$ \begin{array}{r} 4.36 \\ 5.22 - 6.07 \\ 5.50 \end{array} $	$\begin{array}{c} 3.0 \\ 5.5-6.0 \\ 2.0-2.5 \end{array}$
Tellurides: Nagyagite, Au, Pb, Sb, Te, S Tetradymite, Bi, Te, S Petzite (Ag, Au) Te	6.68-7.20 7.41 8.83	1.0-1.5 1.5-2.0 2.5-3.0
Sylvanite, AuAgTe ₄	8.28 4.89	5.0-6.0
Tungstates: Scheelite, CaWO4	6.07	4.5-5.0 5.0-5.5
Vanadates: Descloizite Vanadinite, PbsCl(VO4)2	5.84	3.0-5.0 3.0
Combustibles: Anthracite	1.34-1.46 0.83-1.16	• • • • • • • •
Bituminous Lignite		• • • • • • •

The Principal Concentrating Ores and Gangues¹

Lead: 7.26-7.60 2.0-3.0 Cerussite 6.57 3.75 Anglesite 6.26-6.30 3.0 Copper: Melaconite 6.0 3.0-4.0 Cuprite 3.09-4.02 2.0-1.0 Chalcoeite 5.78 2.75 Bornite 4.40-5.50 3.0 Chalcopyrite 4.17 3.5-4.0 Malachite 3.03 3.5-4.0 Chrysocolla 2.00-2.20 2.0-4.0 Iron: Magnetite 4.94-5.18 5.5-6.0 Magnetite 4.94-5.18 5.5-6.0 6.6-6.5 Marcasite 4.77-4.86 6.0-6.5 6.0-6.5 Pyrrhotite 4.30-4.45 5.0 6.0-6.5 Sphalerite 4.02 4.0 5.0 Sphalerite 4.01 5.0 7.0 Willemite 4.01 5.0 7.0 Gangues: Barite (heavy spar) 4.48-4.72 3.0-3.5 Manganese garnet 4.0-4.50 7.0 Iron g		Specific gravity	Hardness
Cerussite. 6.57 3.75 Anglesite. 6.26-6.30 3.0 Copper: -			
Anglesite. 6.26-6.30 3.0 Copper:			
Copper: Melaconite 6.0 3.0-4.0 Cuprite 3.09-4.02 Chalcocite 5.78 2.75 Bornite 4.40-5.50 3.0 Chalcopyrite 4.17 3.5-4.0 Malachite 2.00-2.20 2.0-4.0 Iron: Mispickel 5.22-6.07 5.5-6.0 Magnetite 4.94-5.18 5.8-6.5 9.7 Pyrite 4.85-5.04 6.0-6.5 6.0-6.5 Marcasite 4.77-4.86 6.0-8.5 7.0 Pyrrhotite 4.62 4.0 3.5-4.0 Sphalerite 4.09 3.5-4.0 3.5-4.0 Willemite 4.09 3.5-4.0 3.0 Sphalerite 4.09 3.5-4.0 3.0 Willemite 4.09 3.5-4.0 3.0 Sphalerite 4.09 3.5-4.0 3.0 Manganese garnet 4.09 3.5-4.0 3.0 Manganese garnet 4.04-4.50 7.0 Lime garnet 3.0-4.0			
Melaconite 6.0 3.0-4.0 Cuprite 3.09-4.02 2.75 Chalcocite 5.78 2.75 Bornite 4.40-5.50 3.0 Chalcopyrite 4.17 3.5-4.0 Malachite 3.93 3.5-4.0 Chrysocolla 2.00-2.20 2.0-4.0 Iron: Mispickel 5.22-6.07 5.5-6.0 Magnetite 4.94-5.13 5.5-6.5 Pyrite 4.94-5.13 5.5-6.5 Pyrite 4.94-5.13 5.5-6.5 Pyrite 4.94-5.13 5.6-6.5 Pyrite 4.94-5.13 5.6-6.5 Pyrite 4.04-5.13 5.6-6.5 Pyrite 4.04-5.13 5.6-6.5 Pyrite 4.02 4.0 Zinc: Smithsonite 4.02 4.0 Sphalerite 4.09 3.5-4.0 Willemite 4.09 3.5-4.0 Sphalerite 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0	Anglesite	6.26-6.30	3.0
Melaconite 6.0 3.0-4.0 Cuprite 3.09-4.02 2.75 Chalcocite 5.78 2.75 Bornite 4.40-5.50 3.0 Chalcopyrite 4.17 3.5-4.0 Malachite 3.93 3.5-4.0 Chrysocolla 2.00-2.20 2.0-4.0 Iron: Mispickel 5.22-6.07 5.5-6.0 Magnetite 4.94-5.13 5.5-6.5 Pyrite 4.94-5.13 5.5-6.5 Pyrite 4.94-5.13 5.5-6.5 Pyrite 4.94-5.13 5.6-6.5 Pyrite 4.94-5.13 5.6-6.5 Pyrite 4.04-5.13 5.6-6.5 Pyrite 4.04-5.13 5.6-6.5 Pyrite 4.02 4.0 Zinc: Smithsonite 4.02 4.0 Sphalerite 4.09 3.5-4.0 Willemite 4.09 3.5-4.0 Sphalerite 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0	Copper: -		
Cuprite 3.99-4.02 2.75 Chalcootie 5.78 2.75 Bornite 4.40-5.50 3.0 Chalcopyrite 4.17 3.5-4.0 Malachite 3.93 3.5-4.0 Chrysocolla 2.00-2.20 2.0-4.0 Iron: Mispickel 5.22-6.07 5.5-6.0 Magnetite 4.94-5.18 5.5-6.5 7.0 Pyrite 4.85-5.04 6.0-6.5 6.0-6.5 Marcasite 4.77-4.86 6.0-6.5 6.0-6.5 Pyrrhotite 4.62 4.0 Zinc: Smithsonite 4.02 4.0 Sphalerite 4.09 3.5-4.0 Willemite 4.01 5.0 Gangues: Barite (heavy spar) 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Iron garnet 3.90-4.40 7.0 Ime garnet 3.90-4.40 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96		6.0	3.0 - 4.0
Chalcoeite 5.78 2.75 Bornite 4.40-5.50 3.0 Chalcopyrite 4.17 3.5-4.0 Malachite 3.93 3.5-4.0 Chrysocolla 2.00-2.20 2.0-4.0 Iron: Mispickel 5.22-6.07 5.5-6.0 Magnetite 4.94-5.18 5.5-6.5 Pyrite 4.94-5.18 5.5-6.5 Pyrite 4.94-5.18 5.5-6.5 Pyrrhotite 4.77-4.86 6.0-6.5 Pyrrhotite 4.62 4.0 Zinc: Smithsonite 4.02 4.0 Zinc: Smithsonite 4.09 3.5-4.0 Willemite 4.01 5.0 Gangues: Barite (heavy spar) 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Iron garnet 3.90-4.40 7.0 Inon garnet 3.40-3.50 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Oblomite 2.83-		3.09 - 4.02	
Chalcopyrite 4.17 3.5-4.0 Malachite 3.03 3.5-4.0 Chrysocolla 2.00-2.20 2.0-4.0 Iron: Mispickel 5.22-6.07 5.5-6.0 Magnetite 4.94-5.18 5.5-6.5 Pyrite 4.85-5.04 6.0-6.5 Pyrite 4.85-5.04 6.0-6.5 4.0-6.5 Marcasite 4.77-4.86 6.0-6.5 Pyrrhotite 4.02 4.0 3.5-4.0 3.5-4.0 3.0 Zinc: Smithsonite 4.35-5.04 6.0-6.5 5.0 5.0 Sphalerite 4.02 3.5-4.0 3.5-4.0 3.0 3.5-4.0 3.0 3.5-4.0 3.0 3.5-4.0 3.0 3.0 3.5-4.0 3.0 3.5-4.0 3.0 3.5-4.0 3.0 3.5-4.0 3.0 3.5-4.0 3.0 3.5-4.0 3.0 3.5-4.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 <		5.78	2.75
Malachite. 3.93 3.5-4.0 Chrysocolla. 2.00-2.20 2.0-4.0 Iron: Mispickel. 5.22-6.07 5.5-6.0 Magnetite. 4.94-5.18 5.5-6.5 Pyrite. 4.85-5.04 6.0-6.5 Marcasite. 4.77-4.86 6.0-6.5 Pyrrhotite. 4.62 4.0 Zinc: Smithsonite. 4.09 3.5-4.0 Sphalerite. 4.09 3.5-4.0 Willemite 4.01 5.0 Gangues: Barite (heavy spar) 4.48-4.72 3.0-3.5-1 Manganese garnet 4.10-4.50 7.0 Iron garnet. 3.90-4.40 7.0 Lime garnet 3.40-3.50 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Dolomite 2.83-2.94 3.5-4.0 Quarts 2.50-2.80 7.0 Calcite 2.70-2.73 3.0 Kaolimite 2.40-2.60 1.0 Hematite 4.50-5.30 5.5-6.5 Serpentine 2.6	Bornite	4.40 - 5.50	3.0
Malachite. 3.93 3.5-4.0 Chrysocolla 2.00-2.20 2.0-4.0 Iron: Mispickel 5.22-6.07 5.5-6.0 Magnetite 4.94-5.18 5.5-6.5 Pyrite 4.85-5.04 6.0-6.5 Marcasite 4.77-4.86 6.0-6.5 Pyrrhotite 4.62 4.0 Zinc: Smithsonite 4.09 3.5-4.0 Willemite 4.01 5.0 Gangues: Barite (heavy spar) 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Line garnet 3.90-4.40 7.0 Lime garnet 3.40-3.50 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Dolomite 2.83-2.94 3.5-4.0 Quarts 2.50-2.80 7.0 Calcite 2.70-2.73 3.0 Kaolimite 2.40-2.60 1.0 Hematite 2.6 3.0-4.0 Spinel 3.50-3.60 8.0 Tale 2.50-2.80 1.0<		4.17	3.5 - 4.0
Iron: Mispickel		3.93	3.5 - 4.0
Mispickel. 5.22-6.07 5.5-6.0 Magnetite. 4.94-5.18 5.5-6.5 Pyrite. 4.85-5.04 6.0-6.5 Marcasite. 4.77-4.86 6.0-6.5 Pyrrhotite. 4.62 4.0 Zinc: Smithsonite 4.09 3.5-4.0 Sphalerite. 4.09 3.5-4.0 Willemite. 4.01 5.0 Gangues: 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Lime garnet. 3.90-4.40 7.0 Lime garnet. 3.40-3.50 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Dolomite. 2.83-2.94 3.5-4.0 Quarts. 2.50-2.80 7.0 Calcite. 2.70-2.73 3.0 Kaolimite. 2.40-2.60 1.0 Hematite. 4.50-5.30 5.5-6.5 Serpentine. 2.6 3.0-4.0 Spinel. 3.50-3.60 8.0 Tale. 2.50-2.80 1.0 Monazi	Chrysocolla	2.00 - 2.20	2.0 - 4.0
Mispickel. 5.22-6.07 5.5-6.0 Magnetite. 4.94-5.18 5.5-6.5 Pyrite. 4.85-5.04 6.0-6.5 Marcasite. 4.77-4.86 6.0-6.5 Pyrrhotite. 4.62 4.0 Zinc: Smithsonite 4.09 3.5-4.0 Sphalerite. 4.09 3.5-4.0 Willemite. 4.01 5.0 Gangues: 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Lime garnet. 3.90-4.40 7.0 Lime garnet. 3.40-3.50 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Dolomite. 2.83-2.94 3.5-4.0 Quarts. 2.50-2.80 7.0 Calcite. 2.70-2.73 3.0 Kaolimite. 2.40-2.60 1.0 Hematite. 4.50-5.30 5.5-6.5 Serpentine. 2.6 3.0-4.0 Spinel. 3.50-3.60 8.0 Tale. 2.50-2.80 1.0 Monazi	Iron:		
Magnetite 4.94-5.18 5.5-6.5 Pyrite 4.85-5.04 6.0-6.5 Marcasite 4.77-4.86 6.0-6.5 Pyrrhotite 4.62 4.0 Zinc: Smithsonite 4.09 3.5-4.0 Sphalerite 4.09 3.5-4.0 Willemite 4.01 5.0 Gangues: Barite (heavy spar) 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Iron garnet 3.90-4.40 7.0 Lime garnet 3.40-3.50 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Dolomite 2.83-2.94 3.5-4.0 Quarts 2.50-2.80 7.0 Calcite 2.70-2.73 3.0 Ksolimite 2.40-2.60 1.0 Hematite 4.50-5.30 5.5-6.5 Serpentine 2.6 3.0-4.0 Spinel 3.50-3.60 8.0 Talc 5.0 5.2 Pitchblende 6.4 5.5 Ru		5.22-6.07	5.5-6.0
Pyrite. 4.85-5.04 6.0-6.5 Marcasite 4.77-4.86 6.0-6.5 Pyrrhotite 4.62 4.0 Zinc: Smithsonite 4.30-4.45 5.0 Sphalerite 4.09 3.5-4.0 Willemite 4.01 5.0 Gangues: Barite (heavy spar) 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Iron garnet 3.90-4.40 7.0 Lime garnet 3.40-3.50 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Dolomite 2.83-2.94 3.5-4.0 Quarts 2.50-2.80 7.0 Calcite 2.70-2.73 3.0 Kaolimite 2.40-2.60 1.0 Hematite 4.50-5.30 5.5-6.5 Serpentine 2.6 3.0-4.0 Spinel 3.50-3.60 8.0 Tale 2.50-2.80 1.0 Miscellaneous: 4.6 5			
Marcasite 4.77-4.86 6.0-6.5 Pyrrhotite 4.62 4.0 Zinc: Smithsonite 5.0 Sphalerite 4.09 3.5-4.0 Willemite 4.01 5.0 Gangues: Barite (heavy spar) 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Iron garnet 3.90-4.40 7.0 Lime garnet 3.40-3.50 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Dolomite 2.83-2.94 3.5-4.0 Quarts 2.50-2.80 7.0 Calcite 2.70-2.73 3.0 Kaolimite 2.40-2.60 1.0 Hematite 2.6 3.0-4.0 Spinel 3.50-3.60 8.0 Talc 2.50-2.80 1.0 Miscellaneous: 4.0 5.0 Hornblende 6.4 5.5 Rutile 4.20-4.30 6.0-6.5 <td< td=""><td></td><td>_</td><td></td></td<>		_	
Pyrrhotite 4.62 4.0 Zinc: Smithsonite 4.30-4.45 5.0 Sphalerite 4.09 3.5-4.0 Willemite 4.01 5.0 Gangues: Barite (heavy spar) 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Iron garnet 3.40-3.50 7.0 Lime garnet (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Dolomite 2.83-2.94 3.5-4.0 Quarts 2.50-2.80 7.0 Calcite 2.70-2.73 3.0 Kaolimite 2.40-2.60 1.0 Hematite 4.50-5.30 5.5-6.5 Serpentine 2.6 3.0-4.0 Spinel 3.50-3.60 8.0 Talc 2.50-2.80 1.0 Miscellaneous: 4.0 5.5 Rutile 4.20-4.30 6.0-6.5 Thorianite 8.00-9.70 7.0 Thorianite 4.6			
Zinc: Smithsonite 4.30-4.45 5.0 Sphalerite 4.09 3.5-4.0 Willemite 4.01 5.0 Gangues: Barite (heavy spar) 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Iron garnet 3.90-4.40 7.0 Lime garnet 3.40-3.50 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Dolomite 2.83-2.94 3.5-4.0 Quarts 2.50-2.80 7.0 Calcite 2.70-2.73 3.0 Kaolimite 2.40-2.60 1.0 Hematite 2.6 3.0-4.0 Spinel 3.50-3.60 8.0 Talc 2.50-2.80 1.0 Miscellaneous: 4.0 5.5 Rutile 5.0 5.2 Pitchblende 6.4 5.5 Rutile 4.20-4.30 6.0-6.5 Thorianite 8.00-9.70 7.0 Thorite 4.6 Wolframite 7.10-7.90			
Smithsonite 4.30-4.45 5.0 Sphalerite 4.09 3.5-4.0 Willemite 4.01 5.0 Gangues: 3.5-4.0 Barite (heavy spar) 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Iron garnet 3.90-4.40 7.0 Lime garnet 3.40-3.50 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Dolomite 2.83-2.94 3.5-4.0 Quarts 2.50-2.80 7.0 Calcite 2.70-2.73 3.0 Kaolimite 2.40-2.60 1.0 Hematite 2.6 3.0-4.0 Spinel 3.50-3.60 8.0 Talo 2.50-2.80 1.0 Miscellaneous: 5.0 5.2 Hornblende 5.0 5.2 Pitchblende 6.4 5.5 Rutile 4.20-4.30 6.0-6.5 Thorianite 8.00-9.70 7.0 Thorite 4.6	•		
Sphalerite 4.09 3.5-4.0 Willemite 4.01 5.0 Gangues: 3.0-3.5 Barite (heavy spar) 4.48-4.72 3.0-3.5 Manganese garnet 4.10-4.50 7.0 Iron garnet 3.90-4.40 7.0 Lime garnet 3.40-3.50 7.0 Fluorite (fluorspar) 3.14-3.19 4.0 Anhydrite (gypsum) 2.90-2.96 1.5-2.0 Dolomite 2.83-2.94 3.5-4.0 Quarts 2.50-2.80 7.0 Calcite 2.70-2.73 3.0 Kaolimite 2.40-2.60 1.0 Hematite 4.50-5.30 5.5-6.5 Serpentine 2.6 3.0-4.0 Spinel 3.50-3.60 8.0 Tale 2.50-2.80 1.0 Miscellaneous: Hornblende 2.90-3.50 5.0-6.0 Monazite 5.0 5.2 Pitchblende 6.4 5.5 Rutile 4.20-4.30 6.0-6.5 Thorianite 4.6 Wolframite 7.10-7.90 5.0-5.5	— · · · · · · · · · · · · · · · · · · ·	4 20_4 45	K ()
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	Grapmo	00=0	

¹ From Megraw's "Practical Data for the Cyanide Plant." For a longer table, based on acid radicals, see p. 178.

SPECIFIC GRAVITY AND ABSOLUTE WEIGHT OF GASES

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Gas	Formula	Molecu- lar wt. 0 = 16	Weight of 1 liter in grams at 0°C. and 760 mm. pressure	Sp. gr. Air = 1	Wt. of 1 cu. ft. in lb. at 32° F. and 29.92 in. pressure
Accessor	C.H.	26.016	1.1708	0.90561	0.07309
Acetylene	C ₂ H ₂	20.010	1.2928	1.0000	0.08071
Aldahada	C ₂ H ₄ O	44.032	1.2828	1.5324	0.08071
Aldehyde	NH:	17.034	0.7708	0.59623	0.12305
Ammonia	C ₂ H ₄ OH	46.048	2.0862	1.6137	0.13024
	C.H.1OH	88.096	4.0696	3.1479	0.13024
Alcohol, amyl	CH.OH	32.032	1.4483	1.1203	0.09042
Argon	Ar	39.88	1.7809	1.3776	0.11118
Arsine	AsH:	77.984	3.4589	2.6755	0.21593
Benzeue	C ₆ H ₆	78.048	3.5821	2.7708	0.22362
Boron chloride	BCl ₃	117.38	5.09	3.937	0.3177
Boron fluoride	BF ₈	68.00	2.99	2.312	0.1867
Bromine	Br ₂	159.84	7.1437	5.5258	0.44597
Butane	C4H10	58.08	2.65	2.050	0.1654
Cyanogen	C ₂ N ₂	52.05	2.335	1.806	0.14577
Chlorine	Cl ₂	70.92	3.222	2.4923	0.20114
Chlorine monoxide	Cl ₂ O	86.92	3.8820	3.0028	0.24235
Chlorine dioxide	ClO ₂	67.96	3.0192	2.3354	0.18848
Carbon dioxide	CO ₂	44.00	1.9768 1.2504	1.5291	0.12341
Carbon monoxide	COCl ₂	28.00 98.92	4.47	0.96720 3.457	0.07806 0.2791
Carbonyl chloride Carbonyl sulphide	COS	60.07	2.721	2.1047	0.16987
Ethane	C ₂ H ₆	30.048	1.3562	1.0496	0.10367
Ethylene	C ₂ H ₄	28.032	1.2609	0.97532	0.07872
Fluorine	F ₂	38.00	1.635	1.2647	0.1021
Helium	He	4.002	0.1782	0.1378	0.01112
Hydrobromic acid	HBr	80.928	3.50	2.707	0.2185
Hydrochloric acid	HCl	36.468	1.6392	1.26794	0.1023 3
Hydrofluoric acid	HF	20.008	0.9220	0.71318	0.05756
Hydriodic acid	ĦI	127.928	3.657	2.8287	0.22830
Hydrogen	H ₂	2.016	0.08987	0.069516	
Hydrogen arsenide	AsH: H:Se	77.984 81.216	3.4589 3.628	2.67755 2.80639	0.21593 0.22650
Hydrogen selenide Hydrogen sulphide	H ₂ S	34.086	1.539	1.1904	0.09607
Hydrogen phosphide	PH:	34.064	1.5293	1.18293	0.09547
Hydrogen telluride	H ₂ Te	129.516	5.80	4.486	0.3621
Hydrocyanic acid	HCN	27.018	1.226	0.9483	0.05920
Iodine	I ₂	253.84	11.271	8.7183	0.70363
Krypton	Kr	82.92	3.708	2.8682	0.23148
Methane	CH ₄	16.032	0.7168	0.55446	0.04475
Neon	Ne	20.0	0.9002	0.69634	0.05620
Methyl chloride	CH ₂ Cl	50.484	2.3045	1.78261	0.14387
Mercury	Hg N2	200.6 28.02	9.0210 1.2057	6.97850 0.93265	0.5631 7 0. 07527
Nitrogen	N_2O	44.02	1.9782	1.53021	0.12350
Nitric oxide	NO	30.01	1.3402	1.03669	0.08367
Nitrogen tetroxide	N ₂ O ₄	92.02	4.1133	3.18178	0.25679
Nitrogen tetroxide	NO:	46.01	2.0567	1.59092	0.12840
Nitrosyl chloride	NOCl	65.47	2.9253	2.26282	0.18262
Oxygen	O ₂	32.00	1.4291	1.02803	0.08921
Phosphine	PH:	34.064	1.5193	1.09788	0.09487
Phosphorus	P4	124.16	5.6318	4.35639	0.35158
Propane	C ₃ H ₃	44.064	1.9660	1.558	0.12273
Propylene	C ₈ H ₆	42.048	1.8783	1.45293	0.11726
Silicon fluoride	SiF ₄	104.3	4.684	3.60490	0.29093
Sulphur dioxide	SO ₂ Xe	64.07 130.2	2.9266 5.851	2.26390 3.7524	0.18264 0.36527
Xenon	Nt Nt	222.4	9.727	7.5241	0.60724
Water	H ₂ O	18.016	0.8063	0.6237	0.050336
		-0.010	1 3.333		

The column headed Weight of 1 liter in grams, etc., is mainly based upon the tables in "Annuaire pour 1914, Bureau des Longitudes" and in the "Annual Tables" published by the International Congress of Applied Chemistry. Other data are compiled from various sources. There is a wide variation in the results for these constants, even between the work of two supposedly equally qualified workers. For that reason I have, in several instances, cut out some of the last decimal places. In part this variation is caused by the effect of surface condensation of gas films on the apparatus worked with and in part it is probably due to the shape of the vessel itself, as set forth by Morley in 1895.

The determination of these constants for gases is by no means a simple problem. So far as possible, the values are those obtained experimentally, and are not simply calculated from atomic weights. In the cases of such substances as mercury, water, etc., the values at 0° and 29.92 in. of mercury pressure are purely theoretical. The experiments for the determination of the constants have been made at higher temperatures and the values in the table calculated from the

equation pv = RmT.

The number of molecules per cubic centimeter of gas under standard conditions is about 27.09×10^{18} .

Velocity of electrons, 2.36×10^{10} to 2.85×10^{10} cm. per

second.

The value of the gas constant in the formula for perfect gases has been calculated by M. D. Berthelot for "Annuaire pour 1914, Bureau des Longitudes." He considers a large number of gases and obtains for the mean value in

$$pv = RT$$

$$R = 0.08207$$

A gram molecule of gas at 0°C. and 760 mm. is 22,380 cc. If a gas be expanded or compressed so quickly that no heat is either absorbed or given off, then $pv^{1.406} = k$.

Critical Temperatures and Pressures¹

The critical temperature of a gas is that temperature above which no pressure suffices to produce a liquid. The pressure at which a gas at the critical temperature begins to become a liquid is known as the critical pressure:

^{1 &}quot;Annuaire par 1914, Bureau des Longitudes."

Substance	Critical tempera- ture, deg. C.	Critical pressure, atmos.	Critical density calculated
Elements: Argon Bromine Chlorine Helium Hydrogen Iodine Krypton Mercury Neon Nitrogen Oxygen Xenon Inorganic substances:	-122.44 302.2 146.0 -267.84 -241.1 512.0 -62.5 1270.0 <205.0 -145.1 -118.8 14.7	48.0 83.9 2.26 11.0 41.24 29.0 33.6 50.8 43.5	0.547 0.043 0.299-0.296 0.400
Ammonia, NH ₂ Carbon monoxide, CO. Carbon dioxide, CO ₂ Carbon disulphide. Carbonyl sulphide, COS. Germanium tetrachloride, GeCl ₄ Hydrochloric acid, HCl. Hydriodic acid, HI. Hydroselenic acid, H ₂ Se. Nitric oxide, N ₂ O ₂ Nitrogen monoxide, N ₂ O. Nitrogen monoxide, NOCl. Phosphine, PH ₂ Phosphorus trichloride, PCl ₂ Silicon hydride, SiH ₄ Silicon tetrachloride, SiCl ₄ Sulphur dioxide, SO ₂ Sulphuretted hydrogen, H ₂ S Tin tetrachloride, SnCl ₄ Water, H ₂ O Organic substances:	131.0 -139.5 31.1 273.05 105.0 276.9 51.8 150.7 137.0 - 93.5 36.5 167.0 51.3 285.5 - 0.5 221.0 157.0 100.4 318.7 364.3	113.0 35.5 73.0 72.87 	0.326 0.460 0.4408 0.462 0.524 0.524
Acetylene, C ₂ H ₂ Alcohol (ethyl), C ₂ H ₅ OH. Benzene, C ₆ H ₆ . Carbon tetrachloride, CCl ₄ . Ethane, C ₂ H ₆ . Ethylene, C ₂ H ₄ . Naphthalene, C ₁₀ H ₈ . Methane, CH ₄ . Pentane, C ₅ H ₁₂ . Phenol, C ₆ H ₅ OH. Toluene, C ₇ H ₈ .	35.5 243.1 288.5 283.15 32.1 9.5 468.2 - 81.8 197.2 419.2 320.6	61.7 62.96 47.89 44.97 49.0 50.8 39.2 54.9 33.0	0.276 0.305 0.558 0.210 0.145 0.232

How to Generate the Various Gases

Acetylene.—Best generated from calcium carbide and water $(CaC_2 + 2H_2O = Ca(OH)_2 + C_2H_2)$. Can also be prepared by the incomplete combustion of coal gas, or by the action of acetylene bromide on alcoholic potash $(C_2H_4Br_2 + 2KOH = C_2H_2 + 2H_2O + 2KBr)$. Can also be bought compressed in cylinders.

Ammonia.—Best generated by the action of calcium oxide on ammonium chloride. Can be bought compressed in cylinders.

Argon.—Can be obtained by depriving air of oxygen with phosphorus, then absorbing the nitrogen by red-hot magnesium.

Arsine.—The gas may be obtained pure by the following

reaction:

$$Sn_2As_2 + 6HCl = 3SnCl_2 + 2AsH_3$$

It is also formed when any arsenious compound comes into contact with nascent hydrogen, which reaction forms the basis for the well-known Marsh test. The other hydride of arsenic, As₂H₄, is a solid.

Bromine.—Best generated by heating the easily purchased

liquid bromine.

Carbon Dioxide.—Best made by the action of hydrochloric acid on marble or sulphuric acid on sodium carbonate.

also be bought compressed.

Carbon Monoxide.—Best made pure by heating oxalic acid with concentrated sulphuric acid and absorbing the carbon dioxide in calcium hydrate emulsion:

$$C_2H_2O_4 + H_2SO_4 = CO_2 + CO + H_2SO_4 \cdot H_2O$$

Can also be made by passing CO₂ over red hot coke or charcoal. This last reaction is not self-sustaining but requires considerable external heat.

Chlorine.—Is readily generated from a mixture of salt, man-

ganese dioxide and sulphuric acid.

(4NaCl + MnO₂ + 4H₂SO₄ = 4HNaSO₄ + 2H₂O + MnCl₂ +

It is also readily purchased compressed in cylinders.

Cyanogen.—This is easily made by heating mercuric cyanide. It is extremely poisonous.

Ethane.—Must be made from a methyl halide, as:

$$2CH_3Cl + 2Na = 2NaCl + C_2H_6$$

Ethylene.—Is best formed by treating an ethyl halide with potassium hydroxide ($C_2H_5Br + KOH = C_2H_4 + KBr + H_2O$) or by treating ethyl alcohol with concentrated sulphuric acid.

Hydrogen.—Formed by the action of hydrochloric or sulphuric acid on metallic zinc, though the gas prepared in this way may contain hydrogen phosphide and arsine, so that it cannot be used for certain purposes. The Lane process produces hydrogen by passing steam over red-hot iron, and reducing the Fe₂O₄ formed with water gas, the iron being again used to produce further quantities of hydrogen. It can also be produced by electrolytic methods (methods of Messerschmidt and of Bergius), and by the reactions Ca(OH)₂ + CO = CaCO₃ + H_2 and $CO + H_2O = CO_2 + H_2$. It is said the hydrogen for Zeppelin inflation is made by starting the decomposition of acetylene electrically, $C_2H_2 = 2C + H_2 + 47,800$ cal. Jaubert's method consists in preparing calcium hydride by passing hydrogen over calcium in an electric furnace, $Ca + H_2 = CaH_2$, then later generating the hydrogen where needed: CaH2 + $2H_2O = Ca(OH)_2 + 2H_2$. Strictly speaking, this is a method of transporting hydrogen rather than of generating it. Jaubert

also has patented a hydrogenite mixture, 5 parts ferrosilicon, 12 parts caustic soda and 4 parts slacked lime. Si + 2NaOH + $Ca(OH)_2 = Na_2SiO_3 + CaO + 2H_2O$. Hydrogen may also be generated by the action of potassium or sodium on water.

Hydrochloric Acid Gas.—Given off by the action of concen-

trated sulphuric acid on aqueous hydrochloric acid.

Hydrocyanic Acid Gas.—This is formed by heating sulphuric acid and sodium cyanide. It is fearfully poisonous.

Hydrogen Phosphide (Phosphine).—This is formed when phosphorus is boiled with strong potash or caustic soda, or caustic lime $(4P + 3NaOH + 3H_2O = 3H_2NaPO_2 + PH_3)$. The gas as thus formed takes fire in contact with air, due to traces of P₂H₄. This compound can be removed by refrigerating mixtures and the resulting gas will not take fire spontaneously. These phosphorous compounds are very poisonous.

Hydrogen Selenide.—Formed by the action of dilute acids or aluminum selenide. This can be made by putting lump selenium in molten aluminum. A mask and gloves should be worn when making the selenide, as the mixture occasionally The utmost precaution should be observed spatters badly.

not to breathe the seleniuretted hydrogen.

Hydrogen Sulphide.—Readily made by treating ferrous sulphide with hydrochloric acid, by the action of sulphuric acid on low-grade mattes, or by melting paraffin and sulphur

together.

Hydrogen Telluride.—Formed by the action of water on aluminum telluride. This is made by putting lumps of tellurium in molten aluminum. The slag which forms on the surface is aluminum telluride. Goggles should be worn when making this compound.

Kakodyl.—[(CH₃)₂As]₂. This is formed by heating arsenious anhydride and potassium acetate in a closed retort. This is ordinarily a fetid, fuming liquid, violent, poisonous, and when

pure, spontaneously inflammable.

Methane.—This is most easily prepared by heating a mixture of 2 parts sodium acetate, 2 parts potassium hydroxide and 3 parts quicklime $(NaC_2H_3O_2 + \overline{R}OH = CH_4 + \overline{R}NaCO_3)$. can also be made by passing carbon disulphide and water vapor over red hot copper $(CS_2 + 2H_2O + 6Cu = CH_4 + 2Cu_2S +$ 2CuO).

Nitric Anhydride.—Prepared by passing dry chlorine over dry

silver nitrate at 95°C.

Nitrous Oxide.—Obtained by heating ammonium nitrate crystals (NH₄NO₃ = N₂O + 2H₂O). The reaction takes place

at comparatively low temperatures.

Nitrogen.—Can be readily obtained by absorbing the oxygen from the air with phosphorus. In this case it contains about one-eightieth of its mass in argon and traces of helium, xenon,

Nitrogen Peroxide.—Obtained by mixing two volumes of dry nitric oxide and one of oxygen together.

Nitric Oxide.—Obtained by the action of nitric acid on copper $(3Cu + 8HNO_3 = 3Cu(NO_3)_2 + H_2O + N_2O_2)$. The gas is colorless, but oxidizes with air to nitrogen peroxide, a reddish-brown gas.

$$(4AgNO_8 + Cl_2 = 4AgCl + 2N_2O_5 + O_2)$$

Oxygen.—Is given off when manganese dioxide or potassium chlorate is heated, or, more safely, on ignition of a mixture of the two. Can also be made cheaply by electrolyzing dilute sulphuric-acid solution. Can be introduced into solution by hydrogen peroxide, sodium peroxide, fuming nitric acid, nitric acid, chloric acid, etc. The compressed gas is a common article of commerce.

Phosphine.—See hydrogen phosphide.
Sulphur Dioxide.—Formed by burning sulphur in air, or if wanted chemically pure, by the action of concentrated boiling sulphuric acid on copper (Cu + 2H₂SO₄ = CuSO₄ + 2H₂O + SO₂).

Sulphur Trioxide.—This is most easily formed by roasting ferric sulphate.

Principal Toxic Gases

The following list, from an address of Prof. I. Guareschi, before the Associazone Chim. Industr. on June 14, 1915, at Turin, is given because of the growing popularity of these compounds in warfare.

Name	Formula	Sp. gr.	Color	Discovered
Chlorine	Cl ₂ 1	2.45	Greenish yellow	Scheele 1774.
Hydrochloric acid	HCl 1	1.26	Colorless	Priestley, 1772.
Chlorine dioxide	ClO ₂ ²	1.28	Reddish yellow	H. Davy, 1815.
Bromine	Br ₂ 1	5.6	Red	Balard, 1823.
Hydrobromic acid	HBr		1	
Nitrogen dioxide	N ₂ O ₂	1.039	Colorless	Priestley, 1772.
Nitrogen peroxide	N2O4 1	2.5	Red	Dulong, Gay-Lussac
Nitrosyl chloride	NOCL 2	2.33	Colorless	Gay-Lussac, 1848.
Carbonyl chloride	COCl ₂ 2	3.5	Colorless	J. Davy, 1812.
Carbon monoxide	CO	0.9674		Lasonne, Priestley.
Carbon dioxide	CO ₂	1.524	Colorless	V. Helmont (XVIIth).
Hydrocyanic acid	HNC 2	0.94	Colorless	Scheele, 1782.
Cyanogen	(CN) ₂	1.808	Colorless	Gay-Lussac, 1815.
Cyanogen chloride	CNCI 2	2.12	Colorless	Berthollet, 1789.
Cyanogen bromide	CNBr 2	3.60	Colorless	Serullas, 1827.
Ammonia	NH:	0.59	Colorless	Priestley, 1775.
Sulphureted hydrogen.	H ₂ S	1.18	Colorless	Scheele, 1777.
Sulphur dioxide	SO ₂ 2	2.247		
Sulphur trioxide	8O ₈ *	2.74	Colorless	XVth century.
Phosphine	PH:	1.178	Colorless	Gengembre, 1785.
Arsine.	AsH:	2.69	Colorless	Scheele, 1775.

¹ Positively stated to be used in warfare.

² Probably being used. Possibly being used.

188 METALLURGISTS AND CHEMISTS' HANDBOOK

FLUORINE GAS AND GASEOUS FLUORINE COMPOUNDS
(All toxic)

Name	Formula	8p. gr.	Color	Discoverer
Fluorine	,F _k	1.264	Yellow Coloriess	Moissan, 1886. Scheele, 1782
Hydroffuoric acid Boron fluoride	H.F.	2,312	Colorless	Gay-Lussac and Thenard, 1809.
Silicon fluoride	SiFa	4.684	Colorless	Schoole, 1782.
Carbon fluoride Fluoform	CHF.	3 09 3.06	Coloriem Coloriem	Mosesan. Mesians.
Methyl diffuoride	CH ₂ F ₂	1.22	Coloriess Coloriess	Dumas and Peligot.
Phosphorus trifluoride. Phosphorus pentafluor-	PF. PF.	3.05 4.5	Coloriess Coloriess	H. Davy. Thorpe.
Phosphoric oxyfluoride	POF,	3.63	Colorless	Moissan.
Phosphorus dichlor- trifluoride	PCl ₂ F ₄	5.41	Colorless	Poulene.
Sulphur fluoride Belanium fluoride	SF. BeF.	5.03	Coloriesa Coloriesa	Moiman and Lebeau Prideaux, 1906.
Nitrosyl fluoride Nitrile fluoride	NOP NO _P F	1.68	Coloriess Coloriess	Gore, 1869. Moissan and Lebeau
Thionyl fluoride	SOF:	3.0	Colorless	Moissan and Lebeau
Sulphur dioxydiffuoride	80,F1	3.55	Colorless	Moissan and Lebeau Fremy
Ethyl fluoride Ethylene fluoride	C ₂ H ₄ F ₂		Colorless	Chabrié.
Propyl fluoride	CaH ₇ F CaH ₇ F	2.16	Colories	Meslans, 1894 Meslans, 1894.
Isobutyl fluoride Allyl fluoride	C ₄ H ₄ F	2.58	Colorless Colorless	Moissan. Meslans,
Acetyl fluoride Chromyl fluoride	CHICOF Croif:	2.16	Coloriess Red	Meslans. Ohvieri, 1880.
Tungeten fluoride Bromine pentafluoride	WF. BrF.	* * * * * *	Coloriess Coloriess	Roscoe Lebeau, 1905,
Iodine pentafluoride	13%		Colorless	Moiman, 1902.

On the subject of toxic gases, the following abstract of a lecture for Prof. Guareschi before the Turin Academy of Science on the properties of soda-lime, will also be of interest. (The abstract is from Chemical Abstracts.)

abstract is from Chemical Abstracts.)

Many reactions which take place with NaOH or KOH or lime either not at all or only at high temperatures occur at

SLIGHTLY TOXIC AND THE RARE TOXIC GASES

Osone	N,O NOCl: HI SbHa SiHa CH:O C = NCHa Cro:Cl: P:Ha	Carbon suboxide Nickel carbonyl Diazomethane Ammonia Boron chloride Boron hydrida Acetylene Methyl chloride Methyl ether Ethyl chloride Methyl phosphide Methyl prosphide Methyl arsenide Dimethyl arsine	NH ₁ BCl ₂ B ₄ H ₁₀ C ₄ H ₁
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the ordinary temperature, and sometimes violently when sodalime is employed. Further, soda-lime constitutes the most efficient agent to combat poisonous, irritating, or tear-producing gases, since it readily absorbs Cl, Br, halogen hydrides, CO2, SO₂, COCl₂, (CN)₂, HCN, cyanogen chloride, bromide and iodide, Schloride, SOCl₂, NOCl, NO₂, AsH₃, SbH₃, H₂S and H₂Se, mercaptans, thiocyanic acid, indole, scatole, aldehydes, chlorocarbonic esters, aromatic chloro and bromo derivatives with the halogen in the side-chain, ethyl bromoacetate and chloroacetoacetate, chloroacetone, bromoacetophenone, acetic anhydride, etc. The soda-lime acts far more energetically when recently prepared and stored in a hermetically sealed vessel. In view of its distinctive behavior it is probable that it contains a compound such as Ca(ONa)₂, OH.Ca.ONa, or OH.Ca.O.Ca.-ONa. One hundred grams of soda-lime in fine granules will absorb 1,500-2,250 cc. of COCl2 if the latter is passed slowly through it, but samples prepared from marble exhibit a considerably lower absorptive capacity; when saturated with CO2, soda-lime, even when dry, is incapable of arresting COCl₂. The latter is absorbed well by aniline and other compounds, but soda-lime appears to be the only absorbent of practical value. H₂S is readily absorbed by soda-lime, which becomes black possibly owing to the formation of Fe sulfide. tion is attended with the development of a very considerable amount of heat, and when the current of gas is mixed with air the soda-lime becomes incandescent, while replacement of the air by O results in a violent explosion. This incandescence is observed only with freshly prepared soda-lime, which should consist of granules 1-3 mm. in diameter. One hundred grams of soda-lime absorb as much as 35 l. of H₂S. Soda-lime also absorbs H₂Se which produces rapid and intense irritation of the mucous membrane of the nose and is capable of paralyzing the sense of smell for some hours or even days. No investigation has been made on the action of soda-lime on H₂Te, which is, however only slightly poisonous. SO₂ is absorbed by sodalime, rapidly at first and subsequently more slowly, 26 l. being taken up by 100 g. NO2 is absorbed readily, but NO only slowly and to a limited extent. The mixture of HCl, NOCl, NO₂Cl and Cl obtained from aqua regia is also rapidly absorbed, and the same is the case at first with (CN)2, of which more than 6 l. are absorbed per 100 g.; the employment of soda-lime to retain the (CN)₂ emitted from blast furnaces is suggested. Cyanogen chloride, bromide, and iodide are likewise absorbed. Soda-lime rapidly absorbs CO2 and serves for the removal of the latter from CO, which at the ordinary temperature is absorbed but slightly or not at all. Like all porous substances, soda-lime absorbs a little NH₃, but forms no compound and allows it to escape; in presence of soda-lime, however, NH₃ causes at the ordinary temperature reactions which otherwise occur only at high temperatures. PH: prepared by passing H into a flask containing 45-50 per cent. KOH solution and a few pieces of P, is spontaneously inflammable, but loses this property when passed through soda-lime; the latter also absorbs P vapor. AsH₂ and SbH₂ are absorbed by soda-lime. The latter may, therefore, be used to purify the H obtained by the action of acid on Fe or Zn, but it will not remove PH₂, which is detected by the green color of the flame. Soda-lime absorbs many of the impurities of coal-gas and takes away its fetid odor; similar purification and deodorization occur with C₂H₂, which is not absorbed by soda-lime. CrO₂Cl₂ is rapidly absorbed, no acid vapor passing. SOCl₂ is immediately decomposed with development of much heat but no incandescence, no trace being allowed to pass. Ethyl chloroformate is absorbed with avidity, heat being developed; only faint alcoholic-

ethereal odor passes: ClCO₂Et + Ca√ | → NaCl + EtOH

+ CaCO₂. Chloroacetone is absorbed with generation of heat and replacement of the irritant vapor by one with a pleasant

odor: CH₂ClCOMe + Ca $\langle I_{NaOH} \rightarrow OHCH_2COMe + NaCl +$

CaO. ω-Bromoacetophenone is absorbed. Ethyl bromoacetate is not fixed. Ethyl a-chloroacetoacetate is readily absorbed. Bromoacetyl bromide is immediately absorbed with liberation of heat. Benzyl bromide and chloride are absorbed. Chlorobenzene is not readily absorbed. Crude xylyl or xylylene bromide, probably a mixture of ω -bromoxylenes and ω , ω' -dibromoxylenes are readily absorbed. Acraldehyde is readily absorbed. Furfuraldehyde is rapidly absorbed with development of heat. CH2O is absorbed. Thioformaldehyde is completely and rapidly fixed. AcH is absorbed with development of heat. Pyrrole is absorbed but slightly or not at all. and skatole are absorbed. S₂Cl₂ is immediately absorbed with heating. Ethyl mercaptan is rapidly absorbed with marked development of heat. Thiophene is fixed either not at all or only in traces. HNC is rapidly absorbed with moderate heating. SO₃ is inefficiently fixed. Acetic anhydride is rapidly absorbed. Various esters undergo hydrolysis. Gases and vapors of putrefaction are absorbed. Products of incomplete combustion of paper, wood, etc., are rendered quite odorless. In presence of soda-lime various synthetic reactions take place at the ordinary temperature; the results obtained in this direction are to be published later.

Gas	Rapidly fatal	Usually fatal in ½ to 1 hour	Usually endur- able ½ to 1 hour	Prolonged exposure usually not harmful
HCl. Br or Cl. 803. HCN. NH3. PH3. H38.	about 1 about 0.3 4-5	1.5 -2.0 0.01-0.06 0.4 -0.5 0.12-0.15 0.5 -1.0 0.4 -0.6 0.5 -0.7 2.0 -3.0	0.05-1.0 0.004 0.05-0.2 0.05-0.06 0.3 -0.4 0.1 -0.2 0.2 -0.3 0.5 -1.0	0.01 0.0001 0.02-0.03 0.02-0.04 0.1 0.1 -0.15 0.22

For use in warfare, according to Prof. Vivian B. Lewes¹ a gas should have at least twice the specific gravity of air, and should, for ease of transportation, be easily liquefiable. The principal substances which can be used in respirators to absorb the gases more commonly used in warfare are: Carbonate or bicarbonate of soda; sodium hyposulphite; potassium iodide; an alkaline iodide used with an alkaline carbonate; a mixture of alkaline carbonates and thiosulphite; hyposulphite, carbonate and glycerin.

Analyses of German Poison Gases³

1. Allyl-iso-thiocyanate (allyl mustard oil) C₃H₅NCS (shell).

2. Benzyl bromide, C₆H₅CH₂Br (shell).

3. Bromo-acetone, CH₂Br.CO.CH₃ (hand grenades).

4. Bromated methyl-ethyl-ketone (bromo-ketone), CH2Br.-CO.C₂H₅ or CH₃.CO.CHBr.CH₃ (shell). Dibrome-ketone, CH₃.CO.CHBr.CH₂Br (shell).

5. Bromine, Br₂ (hand grenades).

6. Chloro-acetone, CH₂Cl.CO.CH₃ (hand grenades).

7. Chlorine, Cl₂ (cloud).

- 8. Chloromethyl-chloroformate (palite), ClCOOCH₂Cl (shell).
- 9. Nitro-trichloro-methane (chloropicrin or nitrochloroform), CCl₂NO₂ (shell).

10. Chlorosulfonic acid, SO₂H.Cl hand grenades and

"smoke pots").

- 11. Dichloro-diethylsulfide (mustard gas), (CH₂ClCH₂)₂S (shell).
 - 12. Dimethyl sulfate, (CH₃)₂SO₄ (hand grenades). 13. Diphenyl-chloro-arsine, (C₆H₅)₂ AsCl (shell).

14. Dichloromethyl ether, (CH₂Cl)₂O (shell).

15. Methyl-chlorosulfonate, CH₃ClSO₃ (hand grenades).

16. Phenyl-carbylamine chloride, C₆H₅NCCl₂ (shell).

17. Phosgene (carbonyl chloride), COCl2 (cloud and shell).

18. Sulfur trioxide, SO₃ (hand grenades and shell).

19. Trichloromethyl-chloroformate (diphosgene, palite), ClCOOCCl, (shell).

20. Xylyl bromide (tolyl bromide), CH₃C₆H₄CH₂Br (shell).

1"Engineering," July 23, 1915, p. 89.

2"Le Genie Civil," Sept. 25, 1915, p. 205.

3 Courtesy McKesson & Robins, New York City.

Incendiary Bombs.—According to Professor Vivian B. Lewes the principal ingredient of incendiary bombs is thermit, ignited by means of amorphous phosphorus. The latter substance is also used by the Germans in a type of shrapnel used for marking the range of artillery. The heat of the explosion converts the amorphous phosphorus into white phosphorus, the combustion of which produces fumes of phosphorus pentoxide, which are visible night and day. Wounds produced by fragments of these shells are poisoned.

Failure of Metals Under Repeated Stresses

Materials subjected to repeated stresses fail eventually, even though the stresses are each less than their elastic limit. The smaller the stress, the greater the number of stresses required

	Torsion	fatigue		ding gue
Materials	Fl	C	Fl	C
	Tons per	sq. in.	Tons pe	r sq. in.
Chrome nickel steel, F5117. Nineteen samples of chrome nickel steel. Manganese steel, F5109. Cast steel. Cast steel. Mild steel plates, high results, Q. Mild steel plates, high results, H. Mild steel plates, high results, R. Mild steel plates, high results, R.	10.70 ¹ 7.03 ¹	0.50 0.70 2.42 0.68 1.91 1.26 1.55 1.11 1.55	14.08 13.86 13.82 14.39	
Mean for above mild steels	9.65	1.37	14.04	5.06
Mild steels, exceptional qualities, Y Mild steels, exceptional qualities, F	7.56 8.64	2.40 1.26	13.30 doubt	5.40 ful
Mild steel plates, low results, J	7.09	1.36 1.26 2.03 1.69 1.43 1.58	9.36 8.94 8.95 8.15 9.69 7.42	5.31 4.76 5.13 5.61 4.53 5.17
Mean	6.47	1.56	8.75	5.09
Mild steel rods, LF. Mild steel rods, LA. Pure nickel rods, NI: Farnley iron rods, FAB. Copper rods as rolled, CU. Copper rods annealed, CU. Aluminum rods as rolled, AL. Cast iron (one sample), Cl. Phosphor bronze rods, as rolled, PB.	6.831 5.971 6.221 6.001 5.501 2.691 2.161 3.981	1.60 0.97 1.83 0.61 0.41 0.97 0.13 1.61		
Magmalium rods, as rolled, MA Duralium rods, as rolled, DA	4.21 ¹ 5.80 ¹	0.78 nega- tive		•••••

¹ These fatigue limits were determined calorimetrically.

to produce rupture. C. E. Stromeyer of Manchester, England, gives the following mathematical expression of these facts. There is some limiting value of stress which would just cause a piece of metal to break in an infinite number of applications. Any stress less than this amount could be repeated forever without breaking the specimen. Any stress greater than this amount would certainly rupture the specimen in a finite number of applications. This stress may be termed the fatigue limit (Fl). If the number of repetitions of stress required to break the specimen be $N; \pm S_n =$ the stress applied (the \pm sign indicates that the stress of S_n in tons per square inch may be applied alternately as a tension or compression, or an alternate twisting and bending); C a constant for the material under discussion; then

$$N = \frac{10^6 C^4}{(S_n - Fl)^4} \text{ or } \pm S_n = Fl + C \sqrt[4]{\frac{10^6}{N}}$$

The constants for various metals are given above.

Some Properties of the Metals¹

Brittleness or Toughness (MARTEN'S Formulæ).—Toughness of test length =

 $\frac{\text{ultimate strength}}{\text{yield point}} \times \frac{\text{per cent. elongation in test length.}}{100}$

The metals then range in this order:

Pb, Pt, Fe, Al, Ni, Zn, Sn, Cu, Au, Ag.

Ductility.—W, Au, Ag, Pt, Fe, Ni, Cu, Al, Zn, Sn, Sb.

By some authorities aluminum is placed fourth; it has been drawn so fine that 11,400 yd. weigh only 1 oz. One ounce of tungsten at 0.0005 inch diam. equals 12,490 yd. (FINK).

Tenacity.—Steel, Ni, Fe, Cu, Al, Au, Zn, Šn, Pb.

Malleability.—Au, Ag, Al, Cu, Sn, Pt, Pb, Zn, Fe, Ni.

The thinest metal leaf commercially attainable in 1914 was: Au, 0.000008 cm.; Al, 0.000020; Ag, 0.000021; Pt, 0.000025; Cu, 0.000034; Dutch metal, 0.00007 (KAYE and LABY).

Plasticity (Marten's Formulæ).—Plasticity = $\frac{\text{toughness}}{\text{yield point}} \times 1000$.

MARTEN'S Classification.—Fe, Pt, Ni, Al, Zn, Cu, Ag, Au,

Pb, Sn.

KURNAKOFF-SCHEMTSCHUSCHNY: K, Na, Pb, Tl, Sn, Bi, Cd, Zn, Sb.

¹ H. O. HOFMAN, "General Metallurgy."

ELASTIC CONSTANTS OF SOLIDS

	Bulk ´ modulus	Coefficient of rigidity	Young's modulus
Brass. Glass. Iron (wrought). Steel Aluminum. Bismuth, cast. Cadmium. Copper. Gold. Lead. Nickel. Palladium. Platinum. Silver. Tin. Bronze. Constantan. Manganin. Zinc. Phosphor bronze.	modulus 10.0 × 10 ¹¹ 4.0 × 10 ¹¹ 14.6 × 10 ¹¹ 18.4 × 10 ¹¹ 7.46 × 10 ¹¹ 3.14 × 10 ¹¹ 4.12 × 10 ¹¹ 13.1 × 10 ¹¹ 16.6 × 10 ¹¹ 17.6 × 10 ¹¹ 17.6 × 10 ¹¹ 17.6 × 10 ¹¹ 17.5 × 10 ¹¹ 10.9 × 10 ¹¹ 24.7 × 10 ¹¹ 10.9 × 10 ¹¹ 5.29 × 10 ¹¹ 15.5 × 10 ¹¹ 12.1 × 10 ¹¹ 12.0 × 10 ¹¹ 12.0 × 10 ¹¹	rigidity 3.7 × 1011 2.4 × 1011 7.7 × 1011 8.2 × 1011 2.63 × 1011 1.20 × 1011 1.92 × 1011 4.55 × 1011 2.80 × 1011 0.562 × 1011 7.7 × 1011 4.04 × 1011 2.86 × 1011 2.97 × 1011 2.97 × 1011 4.65 × 1011 3.8 × 1011 4.36 × 1011	modulus 10.4 × 10 ¹¹ 6.0 × 10 ¹¹ 19.6 × 10 ¹¹ 22.0 × 10 ¹¹ 7.05 × 10 ¹¹ 3.19 × 10 ¹¹ 4.99 × 10 ¹¹ 12.3 × 10 ¹¹ 8.0 × 10 ¹¹ 1.62 × 10 ¹¹ 1.62 × 10 ¹¹ 11.3 × 10 ¹¹ 16.8 × 10 ¹¹ 16.8 × 10 ¹¹ 5.43 × 10 ¹¹ 8.08 × 10 ¹¹ 12.4 × 10 ¹¹ 8.7 × 10 ¹¹ 12.0 × 10 ¹¹
German silver	$\begin{array}{ccc} 4.2 & \times 10^{11} \\ 28.0 & \times 10^{11} \\ 18.6 & \times 10^{11} \end{array}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	11.6 × 10 ¹¹ 42.2 × 10 ¹¹

The above values are mainly from KAYE and LABY's, "Physical and Chemical Constants."

If the volume of a body be altered without changing its shape, the stress divided by the strain is known as the bulk

modulus:
$$k = \frac{v\rho}{\Delta v}$$

If a body be changed in shar, e without changing its volume the modulus of elasticity is the ratio of the stress to the strain which produces it.

Young's Modulus.—The number representing the pressure or tension on a bar in dynes per square centimeter divided by the compression or elongation so produced per centimeter of length.

TENSILE STRENGTH OF SOME METALS AT ORDINARY
TEMPERATURES
(Pounds per square inch)

			
Cobalt	75,000	Aluminum, cast	12,500
Nickel (hard drawn)		Aluminum, rolled	19,290
Iron, rolled		Aluminum, hammered	22,575
Iron, cast		Aluminum, drawn	17,007
Steel (high tensile)	450,000	Tellurium, cast	8,500
Tungsten (hard)	610.000	Zinc	5,000
Platinum, wire, annealed	32,000	Tin, cast	4,600
Platinum, cast		Tin, drawn	5,800
Silver, cast		Bismuth, cast	3,000
Copper, cast		Lead, cast	2,050
Copper, sheet		Lead, pipe	1,650
Copper, bolts		Lead, sheet	1,720
Copper wire, hard drawn		Antimony, cast	1,000
Copper wire, soft drawn	35,500	Tantalum	60,000
Gold, cast		Brass	50,000
Gold wire, hard drawn		German silver	66,000
Gold wire, annealed		Hard rubber	7,000
·	<u> </u>	11	

TENSILE	STRENGTHS	AT LOW	TEMPERATURES ¹
1 ENDILE	DIRENGIAS	AI LUW	IEMPERATURES"

	In kg. per sq. cm.			
	At - 252.6°C.	– 192°C.	+ 17°C.	
Aluminum	4,790	5,370	2,900	
Copper	6,510	4 880	3,580	
CopperGold.		13,400	9,860	
Iron	21,700	19,700	14,700	
Lead	813	581	251	
Nickel	16,500	16,100	11,100	
Platinum	8,600	7,250	5,080	
Silver	6,400	5,390	2,780	

H. O. Hofman, "General Metallurgy."

1 F. A. and C. L. LINDEMANN, Nernst's Festschrift, 1912, p. 264.

TENSILE STRENGTH OF METALS, SHOWING EFFECT OF DRAWING AND ROLLING¹

• .	Lb. per sq. in.				
	Cast	Thin sheet metal	Wire		
German silver Bronze. Brass. Copper. Iron (lengthwise) Iron (crosswise) Steel (lengthwise) Tungsten.	35,960 24,781	39,838-57,350	81,735-92,224 78,049- 81,114-98,578 37,607-62,190 59,246-97,908 103,272-318,823		

¹ Rearranged from tests quoted in Kent's "Mechanical Engineers' Pocket Book."

COEFFICIENTS OF LINEAR EXPANSION PER DEGREE CENTIGRADE¹

	0°-100°	- 190°-0°
Aluminum	0.0000233	0.000183
Antimony	0.0000168	
Antimony (normal to axis)	0.0000089	
Arsenic	0.000017	
Bismuth	0.0000157	0.000013
Brass	0.000019	
Brick	0.0000055	
Bronze	0.0000185	
Cadmium	0.000031	0.0000446
Cement	0.0000143	.
Cobalt	0.0000123	1
Copper	0.0000179	0.0000141
Gas-carbon	0.0000054	
Glass	0.0000085	
Gold	0.0000145	0.0000132

¹ The coefficient of cubic expansion is 3 times the coefficient of linear

expansion.

1 Horman's "General Metallurgy," and" "Annuaire pour 1914, Bureau des Longitudes."

COEFFICIENT OF LINEAR EXPANSION PER DEGREE CENTIGRADE

COEFFICIENT OF DINEAR DAFANSION I		·
	0°-100°	- 190°-0°
Graphite.(artificial)	0.0000025	
Indium	0.0000459	
Invar (63.8 per cent. Fe, 36.2 per]
cent. Ni)	0.0000004	
Iridium	0.0000067	0.0000057
Iron (cast)	0.0000122	0.0000091
lron (wrought)	0.0000119	
Lead	0.0000295	0.0000271
Magnesium	0.0000276	0.0000214
Marble	0.000007	
Mercury (solid)	0.000181	0.000000
Nickel	0.0000132	0.0000101
Osmium	0.0000068	0.0000400
Palladium	0.0000119	0.0000120
Platinum	0.0000090	0.0000088
Potassium	0.000083 0.0000086	• • • • • • • • • • • • • • • • • • • •
Rhodium	0.0000086	••••••
Ruthenium	0.000039	• • • • • • • • • • • • • • • • • • • •
Selenium (40°)	0.000037	••••••
Silver	0.0000195 0.000072	• • • • • • • • • •
Sodium	0.000072	• • • • • • • • • • •
Steel (hardened)	0.000011	
Tellurium	0.0000130	
Thallium	0.000017	
Tin	0.000027	0.0000226
Zinc	0.0000294	0.0000220
Aluminum bronze	0.000017	0.0000204
Brass (Cu 66, Zn 34)	0.0000189	
Bronze (Cu 32, Zn 2, Sn 5)	0.0000177	
Constantan (Cu 60, Ni 40)	0.000017	
German silver (Cu 60, Ni 15, Zn 25).	0.0000184	
Magnalium (Al 86, Mg 13)	0.000024	
Phosphor bronze (Cu 97.6, 2Sn, P 0.2)	0.0000168	
Platinum-iridium (Ir 10 per cent.)	0.0000087	
Solder (Pb 2: Sn 1)	0.000025	
Speculum metal (Cu 68, Sn 32)	0.0000193	
Cement and concrete	0.000010-14	-
Glass, soft 68SiO ₂ , 14Na ₂ O, 7CaO	0.0000085	
Glass, flint 45SiO ₂ , 8K ₂ O, 46PbO	0.0000078	
Granite	0.0000083	
Ice (-10° to 0°)	0.0000507	
Masonry	0.000004-7	
Rubber, hard	0.00004278	
Silica, fused (80° to 0°)	0.00000022	
(0° to 30°)	0.00000042	
(0° to 1000°)	0.00000054	
Sandstone	0.000007-12	
Slate	0.000006-10	

CUBIC EXPANSION OF GASES, PER DEGREE CENTIGRADE ¹
--

	Constant volume	Constant pressure
Air	0.0036650	0.003676
Carbon monoxide	0.0036667	0.0036688
Carbon dioxide	0.003688	0.00371
Cyanogen	0.003829	0.003877
Hydrogen	0.0036678	0.0036613
Nitrogen	0.0036682	0.003670
Oxygen	0.0036741	0.00486
Nitrous oxide	0.003676	0.0037195
Ammonia		0.003854
Sulphur dioxide	0.0038453	0.0039028
Argon	0.003668	
Helium	0.0036627	

CUBIC EXPANSION OF LIQUIDS

Mercury (0°-100°C.)	0.0001818
Water	
Burning oils of sp. gr. 0.795-0.825	0.00072
Benzine	
Light lubricating oil	0.00068
Heavy lubricating oil	
Sodium (liquid)	

Hardness

"The customary hardness test at the present time is that of Brinnell, which consists in making on a flat surface of the material an indentation by means of a small steel ball applied under known pressure. According to Rosenhain perhaps the best definition of hardness is "the power of resisting local displacement of portions of its surface." But it is at once evident that this power is by no means a simple and definite property of the material which will reproduce itself in all circumstances. Thus the displacement of a portion of the substance of a material may occur by plastic flow—the material may be indented at one point while its level is raised at other points; in other circumstances or in other materials the displacement may occur by direct fracture, as in the scratching of a brittle material. Either of these forms of local displacement may be brought about by the application of a steadily increasing force or by a rapidly applied force, i.e., by a shock or blow. It is by no means certain that the power of resisting all these various forms of displacement will be identical or even proportional, so that the material which displays the highest scratch hardness is not necessarily the hardest under an indentation test. Where hardness is referred to, therefore, the manner of measuring it should always be specified.

¹ From "Annuaire pour 1914, Bureau des Longitudes," with a few values from other sources.

Scale of Hardness (Mohs)

"Among the various methods which have been proposed for the measurement of hardness, it seems probable that the Brinnell ball-test, measuring indentation hardness, is probably that one which most nearly approaches our fundamental ideal of constituting a measure of a single definite property. In this case the test probably measures a group of properties of a fairly simple type. That this is the case may be inferred from the fact that tests with balls of different diameter can be rendered fairly comparable."

Hardness = $\frac{\text{load in kg.}}{\text{area of concavity of indentation}} \times \sqrt[5]{\text{radius of ball.}}$

The BRINNELL hardness number is nearly proportional to the ultimate stress determined by tensile tests. On the other hand, ball-hardness number is not a safe guide as to the power to resist abrasion.² A better test for resistance to wear is

¹The materials marked thus (¹) are the standards on this scale. The hardness is determined by scratching an unknown with these standards. One can scarcely determine within half a point what the hardness is. The finger nail may be assumed at about 2.5, and a knife blade at 6.5.

² ROSENHAIN'S "Introduction to Physical Metallurgy."

probably that of the Derihon machine, in which the edge of a hard steel disc revolving in oil is pressed against the test specimen. 1 Some comparative Brinnell numbers and resistances to wear are given below.

BOTTONE'S SCALE OF HARDNESS²

Brinnell Hardness Numbers*

	Cooled in	500 kg.	3000 kg.	Resistance to wear
Phosphor bronse: 10 per cent. Sn. 20 per cent. Sn. 10 per cent. Sn, 10 per cent. Pb. 10 per cent. Sn, 10 per cent. Pb. Gun metal: 10 per cent. Sn, 2 per cent. Zn. 10 per cent. Sn, 2 per cent. Zn. 10 per cent. Sn, 2 per cent. Zn.	Lime Sand Sand	70 86 109 119	107 196 103 69 82 107 137 143	93-100 143-158 80-89 65-70 65-74 86-93 109-119 124-130

(a) 10 mm. ball, applied under 500 kg. pressure 15 seconds.
(b) 10 mm. ball, applied under 3000 kg. pressure 30 seconds.

LATENT HEAT OF EVAPORATION

¹ Proc. Int. Assoc. for Testing Materials, June 1, 1912, p. 3.

Am. Jour. Sci., 1874, Vol. 150, p. 644.

Metaux et Alliages, p. 8, 1915.

Most of these values are from J. W. Richards, "Metallurgical Calculations," a few from Cremer and Bicknell's "Chemical and Metallurgical Handbook."

LATENT HEATS OF FUSION¹

Aluminum	100.0	Mercury	2.83
Antimony ²	40.2^{2}	Nickel	68.0
Bismuth	12.64	Palladium	36.3
Bromine	16.18	Platinum	27.18
Cadmium	13.02	Phosphorus	5.13
Calcium	52.6	Potassium	16.0
Copper	43.3	Potassium nitrate	47.37
Cobalt	68.0	Selenium	13.0
Gallium	19.11	Silicon	127.7
Gold	16.3	Silver	23.5
Ice	79.77	Steel	20.0
Iodine	11.7	Sodium	31.7
Iridium	26.1	Sulphur	9.37
Iron—cast-white	23.0	Thallium	5.8
lron—cast-gray	33.0	Tellurium	19.0
Iron—pure	69.0	<u>Tin</u>	14.0
Lead	5.37	Water	79.76
Magnesium	58.0	Zinc	22.6

Latent Heats of Fusion—Compounds³

Oxides						
Alumina	Al_2O_8	5 0.9				
Silica	SiO_2	76.1				
Titanium oxide	TiO ₂	35.8				
Halie	des					
Arsenic chloride	AsCl.	69.74				
Lead bromide	PbBr ₂	12.34				
Lead chloride	PbCl ₂	20.90				
Manganese chloride	MnCl ₂	49.37				
Stannic chloride	SnCl4	46.84				
Nitrates						
Potassium nitrate	KNO.	48.90				
Sodium nitrate	NaNO	64.87				
Silicates						
Al-calcium silicate (anorthit		CaAl ₂ Si ₂ O ₈	100			
Al-potassium silicate (ortho		KAlSi ₂ O ₈	100			
Al-potassium silicate (micro	•	KAlSi ₂ O ₂	83			
Calcium silicate (wollastoni		CaSiO ₂	100			
Ca-magnesium silicate (mala		Ca ₂ MgSi ₄ O ₁₂	94			
Ca-magnesium silicate (dior		CaMgSi ₂ O ₆	100			
Magnesium silicate (enstati		MgSiO ₃	125			
Magnesium silicate (clistati		Mg ₂ SiO ₄	130			
Iron silicate (fayalite)		Fe ₂ SiO ₄	85			
Hon Sincate (tayante)	•		OU			

¹ Most of these values are from J. W. RICHARD'S "Metallurgical Calculations," a few from CREMER and BICKNELL'S "Chemical and Metallurgical Handbook."

<sup>This is an experimental value. Theory points to a value of about 16.
J. W. Richards, "Metallurgical Calculations."</sup>

Sulphides

Lead sulphide

PbS

104

SPECIFIC HEATS OF NON-METALS AND ALLOYS¹

Material	Specific heat	Material	Specific heat
Solids: Asbestos (20°-100°) Brass (red)	0.20 0.09	Liquids: Alcohol, ethyl (40°) Alcohol methyl (12°)	0.65 0.60
Brass (yellow) Brickwork	0.088 About 0.2	Benzene, C.H. (10°) Benzine.	0.340 0.45
Carbon, graphite Clay	0.16 0.19 0.24	Benzol, (19°-30°)	0.4158 0.53 0.58
Fluorspar (30°)	0.095	Hydrochloric (HCl + 10H ₂ O) (18°) Hydrogen (253°)	0.749 6.00
Glass, flint (10°-50°) Granite (20°-100°) Ice	0.12	KeroseneLead (molten)	0.47 0.03 0.0333
Iron, pure	0.116 0.13	Nitric (HNO _{\bullet} + 10H _{\bullet} O) (189) Nitrogen (-208° to -196°)	0.768 0.43
Iron, wrought	0.11 0.21 0.174	Oil, olive (7°)	0.47 0.35 0.94
Quartz (350°)	0.279 0.19 0.12	Sulphur (119°-147°) Sulphuric (H ₂ SO ₄) (16°-20°) Sulphuric (H ₂ SO ₄ + 5H ₂ O)	0.2346 0.3315
Stone	About 0.2	(16°-20°)	0.5764 0.42

The specific heat of a substance is the number of B.t.u.'s required to raise the temperature of a pound of the substance 1°F. or of 1 kg. of water 1°C. There is much discordant data on the subject and several tables are given. The user is advised to look over all of the tables, as the data is given in several forms.

Specific Heats of Some Metals²

	Specifi	c heat		III	Specifi	c heat	-
Metal	At about 15°C.	At about melting point	As a gas	Metal	At about 15°C.	At about melting point	As a gas
Ag Al Bi Cb Cd Co Fe Hg Ir K Mg W	0.055 0.167 0.030 0.068 0.054 0.106 0.091 0.116 0.033 0.030 0.166 0.941 0.246 0.035	0.076 0.308 0.030 	0.046 0.1852 0.0446 0.025 0.128 0.714 0.2084	Mn Mo Na Ni Os Pb Pt Sr Sb Sn Tl Zn	0.122 0.066 0.293 0.109 0.031 	0.161 0.034 0.046 0.054	0.2174 0.064 0.064 0.416 0.107 0.424 0.024 0.076

¹ From Pierce and Carver's, "Formulas and Tables for Engineers," with some additions from other authorities. For the elements, see the table

on page 202.

The first two columns are from Hofman's "General Metallurgy," the values for the gaseous state are from J. W. RICHARDS "Metallurgical Cal-

Specific Heats of the Elements¹ A table compiled from various sources.

Sub-to- col	Tempera-	Sp.	om various sou	Tempera-	Sp.
Substance ¹	ture ¹	heat ¹	Substance ¹	ture ¹	heat1
Aluminum	-182°-15°	0.168	Lead	300°	0.0338
	17°-100° 600°	0.217 0.282	Lithium	Molten 0°-19°	0.0402 0.837
Antimony	-186°79°	0.0462	LACING	0°-100°	1.093
	1°-20°	0.0503	Magnesium	$-186^{\circ}-79^{\circ}$	0.189
	Molten			17°-100°	0.248
	632°-830°	0.0603	N	2250	0.281
Arsenic: Cryst	0°-100° 21°-65°	0.0822 0.076	Manganese	188°20° 14°97°	0.093
AmorphBarium	-185°-20°	0.068	Mercury	-213°	0.0266
2,001,001	0°-100°	0.05		0°_80°	0.0331
Beryllium	0°-100°	0.425	Molybdenum		0.063
Bismuth	-186°	0.0284	N7: 1 -1	15°-91°	0.072
	22°–100° Molten	0.0304	Nickel	- 186°-18° 18°-100°	0.086
Bromine: Solid		0.084	Nitrogen, liq.		0.43
Liquid	13°-45°	0.107	Osmium	190-980	0.031
Gas	150°-230°	0.0570	Palladium	18°-100°	0.059
Boron, amorph.	0°-100°	0.307	Phosphorus:	W00 400	
Cadmium	-186°79°		Yellow	- 78°-10° 13°-36°	0.17 0.202
Csesium.	Pure 18°-99° 0°-26°	0.055	Yellow Liquid	49°-98°	0.202
Calcium	0°-100°	0.1704	Red	15°-98°	0.17
Carbon	0°-20°	0.145	Platinum	-186°-18°	0.0293
Gas carbon		0.204		18°-100°	0.0324
Charcoal		0.165		1230°	0.0461
Charcoal	0°-224° - 50°	0.238	Potassium Rhodium	- 78°-23° 10°-97°	0.166 0.058
Graphite Graphite	- 50°	0.114 0.160	Ruthemium .	0°-100°	0.061
Graphite	202°	0.297	Selenium:	0 100	0.002
Graphite	977°	0.467	Cryst	22°-62°	0.084
Diamond	11°	0.113	Amorph	18°-38°	0.095
Cerium	0°-100°	0.045	Silicon, cryst.	185°-20°	0.123
Chlorine, liquid	0°-24° -200°	0.226 0.067		57° 232°	0.183 0.203
Chromium	- 200°	0.104	Silver	-186°79°	0.496
	17°-100°	0.110		15°-100°	0.056
	400°	0.133		427°	0.059
Cobalt	$-182^{\circ}-15^{\circ}$	0.082	Sodium: Solid		0.234
	15°-100°	0.103	Solid	100	0.297
Copper	15°-630° -192°-20°	0.123 0.0798	Liquid Sulphur:	128°	0.333
Copper	20°-100°	0.0936	Rhombic	17°-45°	0.163
1	900°	0.118	Liquid	119°-147°	0.235
	Molten	0.1318	Tantalum	-185°-20°	0.033
Didymium	0°-100°	0.046	T-11	58° 15°-100°	0.036
Gallium, solid . Liquid	12°-23° 12°-119°	0.079 0.080	Tellurium Thallium	- 192°-20°	0.0483 0.0300
Germanium	0°-100°	0.074		17°-100°	0.0335
Gold	- 185°-20°	0.035	Thorium	0°-100°	0.028
	18°-990°	0.0303	Tin	$-186-79^{\circ}$	0.0486
	Molten	0.0358		19°-99°	0.0552
Indium	0°-100° 9°-98°	0.057		Molten 240°	0.064
Iodine	Vapor	0.054	Titanium		0.082
Iridium	- 186°-18°	0.0282		0°-100°	0.113
	18°-100°	0.0323		0°-440°	0.162
Iron	$-192^{\circ}-20^{\circ}$	0.089	Tungsten	- 185°-20°	0.036
	20°-100°	0.119	1	20°-100°	0.034
	225° 0°-1100°	0.137 0.153	Uranium Vanadium	0°–98° 0°–100°	0.028 0.115
•	Molten	0.153	Zinc	-233°	0.0268
Lanthanum	0°-100°	0.045		-192°-20°	0.084
Lead	-253°	0.120	1	20°-100°	0.093
	-192°-20°	0.0293	,	300°	0.104 0.068
	15°-100°	0.0309	Zirconium	0°-100°	

¹ See also the table on p. 201.

. Specific Heats of Metals for to Centigrade1

Aluminum	0.2220 + 0.00005t
Antimony	0.04864 + 0.0000084t
Beryllium	0.3756 + 0.00106t
Boron	0.22 + 0.00035t
Carbon (under 250°)	0.1567 + 0.00036t
Carbon (250°-1000°)	0.2142 + 0.000166t
Carbon (above 1,000°)	$0.5 - (120 \div t)$
Nickel (up to 230°)	0.10836 + 0.00002233t
Potassium	0.1858 + 0.00008t
Silicon	0.17 + 0.00009t
Sodium	0.2932 + 0.00019t
Titanium	0.978 + 0.000147t
Zinc	0.0906 + 0.000044t
Bismuth	0.0285 + 0.00002t
Bromine	0.105 + 0.0011t
Copper	0.0917 + 0.000048t
Cadmium	0.0546 + 0.000012t
Iridium	0.0317 + 0.000006t
Lead	0.02925 + 0.000019t
Palladium	0.0582 + 0.00001t
Platinum	0.0317 + 0.000006t
Silver (to 400°)	0.555 + 0.00000943t
Silver (over 400°)	0.5758 + 0.0000044t
	$+0.00000006t^2$
Tin	0.0560 + 0.000044t

SPECIFIC HEATS OF CHLORIDES

Chlorides	Formula	Range	Specific	heat
Ammonium chloride	NH ₄ Cl	23°-100°	0.3908	
Arsenious chloride	AsCla(solid)	14°-98.3°	0.0896	
	AsCla(gas)	159°-268°	0.1122	
Barium chloride	BaCl ₂	140-980	0.0896	
Calcium chloride	CaCl ₂	23°-99°	0.1730	
Chromium chloride	CrCl ₂		0.1430	
Cuprous chloride		17°-98°	0.1383	
Lead chloride		∫ 20°-100°	0.0651	
		160°-380°	0.707	
Lithium chloride		13°-97°	0.2821	
Magnesium chloride	MgCl ₂	24°-100°	0.1946	
Manganese chloride			0.1425	
Mercurous chloride		7°-99°	0.0521	
Mercuric chloride	HgCl:	13°-98°	0.0689	
Potassium chloride	KCl	14°-99°	0.1730	
Silver chloride		160°-380°	0.0978	
Sodium chloride		15°-98°	0.2140	
Strontium chloride	SrCl ₂	13°-98°	0.1199	
Titanium chloride		13°-99°	0.1881	
ent 'v	TiCl ₄ (gas)	163°-271°	0.1290	
Tin (ous)	SnCl ₂	20°-99°	0.1016	
(ic)	SnCl ₄ (solid)	140-980	0.1476	
m:	SnCl ₄ (gas)	149°-273°	0.0939	
Zinc chloride	ZnCl ₂ .	21°-99°	0.1362	

¹ J. W. RICHARDS, "Metallurgical Calculations." ² From Hofman's, "General Metallurgy."

Specific Heats of the Oxides1

Oxide	Formula	Range	Specific heat
Beryllium oxide	BegOs	0°-100°	0.2471
Boron oxide	B ₂ O ₈	16°-98°	0.2374
Antimonious oxide		18°-100°	0.0927
Alumina	Al ₂ O ₂	0°-1200°	0.2081 +
			0.0000876
Alumina	Al ₂ O ₃	above 2200°	0.5935
Arsenious oxide	As ₂ O ₂	13°-97°	0.1276
Calcium oxide	CaO	0°-t°	0.1715+
Calcium Calue	040		0.00007t
Chromium oxide	Crana	10°-99°	0.1796
Ferric oxide	Fe ₂ O ₂	00-40	0.1456+
Ferrie Oxide	L6508	0 -	0.000188
Damana famia a-Ma	To-O	0°-t°	
Ferroso-ferric oxide	Fe ₃ O ₄	0-2	0.1447+
36 1 11	1 3 5 0	040 1000	0.0001884
Magnesium oxide	MgO	24°-100°	0.2440
Magnesium hydrate		19°-50°	0.312
Manganese oxide	MnO	13°-98°	0.157
Manganese sesquioxide		15°-99°	0.162
Manganese sesquioxide,			
hydrated	Mn ₂ O ³ .H ₂ O	21°-52°	0.1760
Manganese peroxide	MnO ₂	17°-48°	0.1590
Nickel oxide	NiO	13°-98°	0.1588
Silica	SiO ₂	0°-1200°	0.1833+
		1	0.000077t
Mercuric oxide	HgO	5°-98°	0.0518
Molybdic oxide	MoOs	21°-52°	0.1540
Lead oxide	PbO	22°-98°	0.0512
Bismuth oxide	Bi ₂ O ₃	20°-98°	0.0605
Thoric oxide	Th ₂ O ₃	0°-100	0.0548
Tin oxide	SnO ₂	16°-98°	0.0936
Titanic oxide	TiO2	0°-200°	0.1790
Tungstic oxide	WO.	8°-98°	0.0798
Zirconium oxide		0°-100°	0.1076
Zinc oxide		0°-1000°	0.1212+
Zine Oxide	ZIIO	0 -1000	0.0000315
Cuprous oxido	Cu ₂ O	19°-51°	0.1110
Cuprous oxide		12°-98°	0.1110
Cupric oxide		. 0°-t°	
Columbic oxide	Cb ₂ O ₅	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	0.1037+
D	E-O		0.00007t
Ferrous oxide		*******	0.1460(a)
Potassium oxide			0.1390(a)
Sodium oxide			0.2250(a)
Lithium oxide	Li ₂ O	1	0.4430(a)

(a) Theoretical results, according to Vogt.

SPECIFIC HEATS OF SULPHATES

Sulphates	Formula	Range	Specific heat
Barium sulphate Calcium sulphate Copper sulphate Lead sulphate Magnesium sulphate Manganese sulphate Nickel sulphate Potassium acid sulphate Potassium sulphate Sodium sulphate Strontium sulphate Zinc sulphate	CaSO4 CuSO4 PbSO4 MgSO4 MnSO4 NiSO4 HKSO4	17°-98° 22°-99°	0.1128 0.1965 0.1840 0.0827 0.2250 0.1820 0.2160 0.2440 0.1901 0.2312 0.1428 0.1740

¹ J. W. RICHARDS, "Metallurgical Calculations," Vol. II.

PHYSICAL CONSTANTS

SPECIFIC HEATS OF NITRATES

Nitrates	Formula	Range	Specific heat
Ammonium nitrate. Barium nitrate. Lead nitrate. Potassium nitrate. Silver nitrate Sodium nitrate. Strontium nitrate. Sodium-potassium nitrate. Sodium nitrate (fused). Potassium nitrate (fused).	Pb(NO ₃) ₂ KNO ₃ AgNO ₃ NaNO ₃ Sr(NO ₃) ₂ KNa(NO ₃) ₂ NaNO ₃ (liquid)	14°-31° 13°-98° 17°-100° 13°-98° 16°-99° 14°-98° 17°-47° 15°-100° 320°-430° 350°-435°	0.4550 0.1523 0.1173 0.2367 0.1435 0.2782 0.1810 0.2350 0.4130 0.3319

SPECIFIC HEATS OF CARBONATES

Carbonates	Formula	Range	Specific heat
Barium carbonate. Calcium carb. (calcite). Calcium carb. (aragonite). Calcium carb. (marble). Calcium-magnesium (dolomite). Iron (siderite). Iron-magnesium. Lead (cerussite). Potassium carbonate. Sodium carbonate. Strontium carbonate.	CaCOs CaCOs CaCOs FeCOs Mg7Fe2(COs)s PbCOs K2COs NasCOs	11°-99° 20°-100° 18°-99° 23°-98° 20°-100° 9°-98° 20°-100° 16°-47° 23°-99° 16°-98° 8°-98°	0.1104 0.2086 0.2085 0.2099 0.2179 0.1935 0.2270 0.0791 0.2162 0.2728 0.1475

Specific Heats of Chromates

Chromates	Formula	Range	Specific heat
Lead chromate	FeCrO ₄ K ₂ Cr ₂ O ₇	19°-50° 19°-50° 16°-98° 19°-98°	0.0900 0.1590 0.1894 0.1851

SPECIFIC HEATS OF BORATES

Borates	Formula	Range	Specific heat
Lead biborate Lead tetraborate Potassium biborate Potassium tetraborate	PbB4O7 K2B2O4	15°-98° 18°-99° 16°-98° 18°-99°	0.905 0.2198 0.2048 0.2198

Specific Heats of Bromides, lodides and Fluorides

Bromides	Formula	Range	Specific heat
	n n	1 400 000	
Lead bromide	PbBr ₂	16°-98°	0.0532
Datassium basmids	KBr	190°-430° 16°-98°	0.0532
Potassium bromide		15°-98°	0.1132 0.0739
Silver bromide	AgBr NaBr	1	0.0739
Cuprous iodide	CuI	200-990	0.0819
Lead iodide	PbI ₂	14°-98°	0.0427
Mercurous iodide	HgI	17°-99°	0.0395
Mercuric iodide	HgI ₂	18°-99°	0.0420
Potassium iodide	ĸĨ	20°-99°	0.0819
Silver iodide	AgI	15°-264°	0.577
Bodium iodide	NaI	16°-99°	0.0868
Clacium fluoride	CaF ₂	15°99°	0.2154
Sodium-aluminum fluoride	Na:AlFe	16°-99°	0.2522
Specific He	ATS OF PHOSPH	ATES	
Phosphates	Formula	Range	Specific
			heat
Talaium acid sheeshate	CaP2Os	15°-98°	0.1992
Calcium acid phosphate		15°-99°	0.1992 0.1903
Calcium phospo-fluoride (apatite) Lead, tribasic diphosphate	Pb ₂ P ₂ O ₄	11°-98°	0.1903
ead pyrophosphate	Pb ₂ P ₂ O ₇	110-980	0.821
otassium pyrophosphate	K ₄ P ₂ O ₇	170-980	0.1901
Silver phosphate	Ag:PO4	19°-50°	0.0898
Sodium pyrophosphate	Na ₄ P ₂ O ₇	17°-98°	0.2283
Specific Heats of A	LUMINATES, Ti	ranates, I	erc.
Aluminates	Formula	Range	Specific heat
· · · · · · · · · · · · · · · · · · ·			
Sninel	MgAl•O4	150-470	0 1940
Spinel	MgAl ₂ O ₄ BeAl ₂ O ₄	15°-47° 0°-100°	0.1940
Chrysoberyl	BeAl ₂ O ₄	0°-100°	0.2004
Chrysoberyl		0°-100° 15°-50°	0.2004 0.177
Chrysoberyllmenite	BeAl:O4 FeTiO3	0°-100° 15°-50° 15°-50°	0.2004
Chrysoberyl	BeAl ₂ O ₄ FeTiO ₂ PbMoO ₄	0°-100° 15°-50° 15°-50° 15°-50° 15°-50°	0.2004 0.177 0.083
Chrysoberyl	BeAlsO4 FeTiOs PbMoO4 CaWO4 Fe(Mn)WO4 KMnO4	0°-100° 15°-50° 15°-50° 15°-50° 15°-50° 15°-15°	0.2004 0.177 0.083 0.097
Chrysoberyl	BeAl ₂ O ₄ FeTiO ₂ PbMoO ₄ CaWO ₄ Fe(Mn)WO ₄ KMnO ₄ KClO ₂	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100°	0.2004 0.177 0.083 0.097 0.098
Chrysoberyl. Climenite Wulfenite Scheelite Wolframite Potassium permanganate Potassiun chlorate Glass	BeAl ₂ O ₄ FeTiO ₂ PbMoO ₄ CaWO ₄ Fe(Mn)WO ₄ KMnO ₄ KClO ₂ Ca,K,SiO ₂	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99°	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977
Chrysoberyl. Imenite Wulfenite Scheelite Wolframite Potassium permanganate Potassiun chlorate Blass Glass, flint	BeAl ₂ O ₄ FeTiO ₃ PbMoO ₄ CaWO ₄ Fe(Mn)WO ₄ KMnO ₄ KClO ₃ Ca,K,SiO ₃	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50°	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.177
Chrysoberyl. Clmenite. Wulfenite. Scheelite. Wolframite. Potassium permanganate. Potassiun chlorate. Glass, flint.	BeAl ₂ O ₄ FeTiO ₃ PbMoO ₄ CaWO ₄ Fe(Mn)WO ₄ KMnO ₄ KClO ₃ Ca,K,SiO ₃	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99°	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977
Chrysoberyl. Chrysoberyl. Climenite. Wulfenite. Cheelite. Wolframite. Potassium permanganate. Potassium chlorate. Glass. Glass, flint. Glass, crown.	BeAl ₂ O ₄ FeTiO ₃ PbMoO ₄ CaWO ₄ Fe(Mn)WO ₄ KMnO ₄ KClO ₃ Ca,K,SiO ₃	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50°	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.177
Chrysoberyl. Climenite. Wulfenite. Scheelite. Wolframite. Potassium permanganate. Potassium chlorate. Glass. Glass, flint. Glass, crown.	BeAl ₂ O ₄ FeTiO ₃ PbMoO ₄ CaWO ₄ Fe(Mn)WO ₄ KMnO ₄ KClO ₃ Ca,K,SiO ₃	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50°	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.177
Sulphides	BeAl ₂ O ₄ FeTiO ₂ PbMoO ₄ CaWO ₄ Fe(Mn)WO ₄ KMnO ₄ KClO ₃ Ca,K,SiO ₃ UND SULPHIDES Formula	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50° Range	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.177 0.161
Chrysoberyl. Climenite. Wulfenite. Scheelite. Wolframite. Potassium permanganate. Potassium chlorate. Glass. Glass, flint. Glass, crown. Composite.	BeAl:O4 FeTiO2 PbMoO4 CaWO4 Fe(Mn)WO4 KMnO4 KClO3 Ca,K,SiO3 UND SULPHIDES Formula Cu:FeS:	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50° Range	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.177 0.161
Chrysoberyl. Climenite. Wulfenite. Scheelite. Wolframite. Potassium permanganate. Potassium chlorate. Glass. Glass, flint. Glass, crown. COMPONE Sulphides Components Comp	BeAl ₂ O ₄ FeTiO ₂ PbMoO ₄ CaWO ₄ Fe(Mn)WO ₄ KMnO ₄ KClO ₃ Ca,K,SiO ₃ UND SULPHIDES Formula Cu ₂ FeS ₂ PbCuSbS ₂	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50° Range	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.161 Specific heat 0.1177 0.0730
Chrysoberyl. Climenite. Wulfenite. Scheelite. Wolframite. Potassium permanganate. Potassium chlorate. Glass. Glass, flint. Glass, crown. COMPOUNT Sulphides Contite. Cobaltite.	BeAl:O4 FeTiO2 PbMoO4 CaWO4 Fe(Mn)WO4 KMnO4 KClO2 Ca,K,SiO3 UND SULPHIDES Formula Cu:FeS2 PbCuSbS2 CoAsS	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50° Range 10°-100° 10°-100° 15°-99°	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.161 Specific heat 0.1177 0.0730 0.0991
Chrysoberyl. Climenite. Wulfenite. Scheelite. Wolframite. Potassium permanganate. Potassium chlorate. Class. Class. Class, flint. Class, crown. COMPOUNT Sulphides Cobaltite. Chalcopyrite.	BeAl ₂ O ₄ FeTiO ₂ PbMoO ₄ CaWO ₄ Fe(Mn)WO ₄ KMnO ₄ KClO ₃ Ca,K,SiO ₃ UND SULPHIDES Formula Cu ₂ FeS ₂ PbCuSbS ₃ CoAsS CuFeS ₂	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50° Range 10°-100° 15°-99° 14°-98°	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.161 Specific heat 0.1177 0.0730 0.0991 0.1310
Chrysoberyl. Climenite. Wulfenite. Scheelite. Wolframite. Potassium permanganate. Potassium chlorate. Glass. Glass, flint. Glass, crown. COMPOUTE Sulphides Connite. Cobaltite. Chalcopyrite. Mispickel	BeAl ₂ O ₄ FeTiO ₃ PbMoO ₄ CaWO ₄ Fe(Mn)WO ₄ KMnO ₄ KClO ₃ Ca,K,SiO ₃ UND SULPHIDES Formula Cu ₂ FeS ₂ PbCuSbS ₃ CoAsS CuFeS ₂ FeAsS.	0°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50° 10°-100° 15°-99° 14°-98° 10°-100°	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.161 Specific heat 0.1177 0.0730 0.0991 0.1310 0.1030
Chrysoberyl Ilmenite Wulfenite Scheelite Wolframite Potassium permanganate Potassium chlorate Glass Glass, flint Glass, crown Compound Sulphides Bournonite Cobaltite Chalcopyrite Mispickel Proustite	BeAl:O4 FeTiO2 PbMoO4 CaWO4 Fe(Mn)WO4 KMnO4 KClO3 Ca,K,SiO3 UND SULPHIDES Formula Cu:FeS: PbCuSbS: CoAsS CuFeS: FeAsS. Ag:AsS:	Range 10°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50° 10°-100° 15°-99° 14°-98° 10°-100° 10°-100°	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.177 0.161 Specific heat 0.1177 0.0730 0.0991 0.1310 0.1030 0.0807
Chrysoberyl Ilmenite Wulfenite Scheelite Wolframite Potassium permanganate Potassium chlorate Glass Glass, flint Glass, crown COMPOU Sulphides Bournonite Cobaltite Chalcopyrite Mispickel Proustite Pyrargyrite	BeAl ₂ O ₄ FeTiO ₂ PbMoO ₄ CaWO ₄ Fe(Mn)WO ₄ KMnO ₄ KClO ₃ Ca,K,SiO ₃ UND SULPHIDES Formula Cu ₂ FeS ₂ PbCuSbS ₃ CuFeS ₂ FeAsS Ag ₂ AsS ₂ Ag ₃ SbS ₃	Range 10°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50° 15°-99° 14°-98° 10°-100° 10°-100° 10°-100° 10°-100° 10°-100° 10°-100°	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.177 0.161 Specific heat 0.1177 0.0730 0.0991 0.1310 0.1030 0.0807 0.0757
Chrysoberyl Imenite Wulfenite Scheelite Volframite Potassium permanganate Potassium chlorate Blass Blass Blass, flint Blass, crown COMPOUNT Sulphides Cobaltite Chalcopyrite Mispickel Proustite	BeAl:O4 FeTiO2 PbMoO4 CaWO4 Fe(Mn)WO4 KMnO4 KClO3 Ca,K,SiO3 UND SULPHIDES Formula Cu:FeS: PbCuSbS: CoAsS CuFeS: FeAsS. Ag:AsS:	Range 10°-100° 15°-50° 15°-50° 15°-50° 15°-15° 10°-100° 14°-99° 10°-50° 10°-100° 15°-99° 14°-98° 10°-100° 10°-100°	0.2004 0.177 0.083 0.097 0.098 0.179 0.210 0.1977 0.177 0.161 Specific heat 0.1177 0.0730 0.0991 0.1310 0.1030 0.0807

SPECIFIC HEATS OF SULPHIDES

Sulphidea	Formula	Range	Specific heat
A-45	ar a	000 000	0.0010
Antimony sulphide	Sb:Sa AaA	23°-99° 20°-100°	0.0840 0 1111
Arsenio sulphide	AtaSa	200-1000	0.1132
Biamuth sulphide	BlaSa	11°-99°	0.0600
Cobalt sulphide	Co8	15* 98°	0.1251
Copper sulphide	CusS	9°-97°	0.1212
	Cu ₂ S	0°-1°	0.1126 +
	71.0		16000001
Ferrous sulphide	FeS	17°-98° 20°-100°	0.1357
Iron pyrites	FerSs FeSs	190-980	0.1301
Lead sulphide	Pb8	160-98	0.0509
Manganese sulphide	MnS	10°-100°	0.1392
Mercury sulphide	HgS	140-980	0 0512
Mercury sulphide	MoS ₂	20°-100°	0.1233
Nickel aulphide	NiS	15°-98°	0 1281
Silver sulphide	Ags	7° 98°	0.0746
	AgnS	0°-t°	0 0685+
Ct	#- H	1 00 000	0.000058
Zino sulphide	ZnS SnS	15°-98° 13°-98°	0.1230 0.0837
Stannie sulphide.	SnS ₂	120-950	0.1193
Stands supmed	Onos	12 -50	0.1100
Specific Heats of A	RSENIDES AND	Antimonii	DES
Antimonides	Formula	Range	Specific heat
Domeykite	CusAs	10°-100°	0.0949
Dyscramite	AgaSb	10°-100°	0.0558
Löllingite	FeAs:	10°-100°	0.0864
Smaltite	CoAse	10°-100°	0.0830
Specific I	TEATS OF SILICA	TES	
Silicates	Formula	Range	Specific
Stitueses	Formula	range	heat
Aluminum milicate (topas)	AlsBi(F)Os	12°-100°	0.1997
Al-calcium silicate (anorthite)	CaAleSiaOa	0°-100°	0.189
	CaAlaSiaOs	0°-1200°	0.294
Al-beryllium silicate (beryl)	BeAlsSisOs	12°-100°	0.2066
Al-potassium silicate (microcline)	KAlSi ₈ O ₁	20°-100°	0.197
Al-potassium milicate (orthoclass)	KAlSi ₂ O ₄	20°-100°	0.1877
Calcium silicate (wollastonite)	CaSiO ₄	0° -100°	0.179
Ca-magnesium ailicate (diopside)		0°-1200° 0°-100°	0.288 0.194
Ca-magnesium silicate (mala-	CaMgSirOs CasMgSisO12	0°-1200° 0°-100°	0.281 0.186
colite)	CasMgSi ₄ O ₁₂	0° 1200°	0.264
Iron silicate (fayalite)	FesSiO4	0°-100°	0.170 .
Iron-aluminum (garnet)	FesAlsSisOts	16°-100°	0.1758
Magnesium silicate (enstatite)	MgSiO:	0°100°	0.206
	MgSiO ₁	0°-1200°	0.301
		0°-100°	0.2200
Magnesium ellicate (olivine)	Mg:BiOs		
Zirconium zilicate (zircon)	ZrSiO ₄	15°-100°	0.1456
Zirconium zilicate (sircon) Basalt	ZrŠiO4	15° -100° 20°-470°	0.1456 0.1990
Zirconium zilicate (zircon)	ZrŠiO₄	15°-100° 20°-470° 14°-99°	0.1456

SPECIFIC HEAT OF WATER¹ (Defining specific heat at 0° to 1°C. as unity)

Tempera- ture, deg. F.	Specific heat	Tempera- ture, deg. F.	Specific heat	Tempera- ture, deg. F.	Specific heat
32	1.0000	176	1.0089	320	1.0294
50	1.0005	194	1.0109	338	1.0328
68	1.0012	212	1.0130	356	1.0364
86	1.0020	230	1.0153	374	1.0407
104	1.0030	248	1.0177	392	1.0440
122	1.0042	266	1.0204	410	1.0481
140	1.0056	284	1.0232	428	1.0524
158	1.0072	302	1.0262	446	1.0568

SPECIFIC HEAT OF WATER (Defining specific heat at 16° to 17° as unity)

Tempera- ture, deg. C.	Specific heat	Thermal capacity, 0° - t°	Tem- perature, deg. C.	Specific heat	Thermal capacity,
0	1.00940	0.00000	25	0.99806	25.05131
0 1 2 3 4	1.00855	1.00898	26	0.99795	26.04932
2	1.00770	2.01710	27	0.99784	27.04720
3	1.00690	3.02440	28	0.99774	28.04499
4	1.00610	4.03090	29	099766	29.04269
5	1.00530	5.03660	30	0.99759	30.04031
6	1.00450	6.04150	31	0.99752	31.03786
7	1.00390	7.04570	32	0.99747	32.03536
5 6 7 8 9	1.00330	8.04930	33	0.99742	33.03280
9	1.00276	9.05233	34	0.99738	34.03020
10	1.00230	10.05486	35	0.99735	35.02757
īĭ l	1.00185	11.05694	36	0.99733	36.02491
$\tilde{1}\tilde{2}$	1.00143	12.05858	37	0.99732	37.02224
13	1.00100	13.05980	38	0.99732	38.01956
14	1.00064	14.06062	39	0.99733	39.01689
15	1.00030	15.06109	40	0.99735	40.01422
16	1.00000	16.06124	41	0.99738	41.01159
17	0.99970	17.06109	42	0.99743	42.00899
18	0.99941	18.06064	43	0.99748	43.00644
19	0.99918	19.05994	44	0.99753	44.00395
20	0.99895	20.05900	45	0.99760	45.00152
21	0.99872	21.05783	46	0.99767	45.99916
22	0.99853	22.05645	47	0.99774	46.99686
23	0.99836	23.05490	48	0.99781	47.99464
24	0.99820	24.05318	49	0.99790	48.99250
25	0.99806	25.05131	50	0.99800	49.99045

¹ From "The Petroleum Year Book, 1914."

MEAN SPECIFIC HEATS OF GASES

	Under constant pressure	Under constant volume	γ
Air, 20°C. Ammonia. Bromine, 19°-388°. Carbon dioxide, 0°. Carbon disulphide, 86°-190°. Carbon monoxide, 23°-99°. Chlorine. Hydrogen. Methane. Nitrogen, 0°C. Nitrous oxide. Oxygen. Sulphur dioxide. Water. Hydrochloric acid.	0.2417 0.5256 0.0555 0.2010 0.1596 0.2425 0.1241 3.4090 0.5929 0.2350 0.2262 0.2175 0.1544 0.4805 0.1867	0.1684 0.391 0.0429 0.172 0.131 0.1736 0.0928 2.411 0.486 0.1727 0.181 0.1723 0.123 0.370	1.402 1.336 1.30 1.239 1.401 1.33 1.42 1.313 1.41 1.324 1.41— (500°) 1.2 1.305
Acetylene. Argon, 20°-90°C. Iodine, 206°-377°C. Nitric oxide, 13°-172°. Nitrogen peroxide, 27°-67°. Sulphuretted hydrogen, 20°-206°. Ethane. Ethylene. Benzene, 34°-115°. Turpentine, 179°-249°.	0.123 0.034 0.232 1.625 0.245		1.26 1.394 (150°) 1.31 1.340 1.22 1.264 (20°) 1.40

Molecular Specific Heats (Lewis & Randall)

These are the ordinary specific heats multiplied by the molecular weight of

N₂, O₂, HCl, HBr, HI, $C_p = 6.5 + 0.0010t$ H₂ $C_p = 6.5 + 0.0009t$. Cl₂, Br₂, I₂, $C_p = 6.65 + 0.004t$. H₂O, H₂S $C_p = 8.81 + 0.0019t + 0.0000222t^2$ CO₂, SO₂ $C_p = 7.0 + 0.0071t + 0.0000018t^2$

Specific Heat of Gases¹

(Calories per gram of gas at t° C. (absolute temperature = t + 273))

	According to Richards	According to Damour
Nitrogen (to 2000°C.) Nitrogen (2000°-4000°C.) Oxygen (to 2000°C.) Oxygen (2000°-4000°C.) Water vapor Carbon dioxide Sulphur dioxide Carbon monoxide Hydrogen Methane Hydrogen (2000°-4000°C.)	$\begin{array}{c} 0.2104 + 0.0000187t \\ 0.1788 + 0.00005t \\ 0.42 + 0.000185t \\ 0.19 + 0.00011t \\ 0.125 + 0.0001t \\ 0.2405 + 0.0000214t \end{array}$	0.2438 + 0.0000214t $0.2135 + 0.0000187t$ $0.447 + 0.000162t$ $0.194 + 0.000084t$ $0.2438 + 0.0000214t$ $3.412 + 0.000300t$ $0.381 + 0.0000234t$

¹ SOMERMEIER'S "Coal." 14

Table of Mean Specific Heats Calories per gram of gas

·	Richards		Daı	mour	Lewis & Randell		
	0°-300°	0°-1000°	0°-300°	0°-1000°	0°-300°	0°-1000°	
Nitrogen	0.247	0.262	0.250	0.265	0.247	0.259	
Oxygen Carbon di-	0.216	0.229	0.219	0.232	0.216	0.227	
oxide	0.223	0.300	0.219	0.278	0.219	0.248	
Water vapor. Carbon mon-	0.476	0.605	0.497	0.610	0.469	0.512	
oxide	0.247	0.262	0.250	0.265	0.247	0.260	
Air	0.240	0.257	0.247	0.258	0.240	0.252	
oxide	0.155	0.225		l	0.150	0.170	
Hydrogen Methane	3.460	3.670	3.502 0.723	3.712 0.986	3.41	3.57	

Specific Heat of Gases, By Volume¹

	Cal. per cu. m. of gas, per deg. C.	Lbcal. per cu. ft. of gas, per deg. C.
Nitrogen. Water vapor. Carbon dioxide. Carbon monoxide. Sulphur dioxide. Hydrogen. Hydrogen (2000°-4000°). Oxygen.	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.0189 + 0.0000017t 0.0189 + 0.0000017t 0.0161 + 0.0000045t 0.0189 + 0.0000017t

Total Heat Contained at Melting Point of Metals1

The heat is expressed in calories necessary to heat 1 gram of the metal to its melting point from 0°C. The latent heat of fusion is then the difference between the heat in the solid and that in the liquid phases.

Element	Melting point	Heat in solid	Heat in liquid	Latent heat of fusion
Aluminum	625.0	158.3	258.3	100.0
Alumina	2200.0	882.0	933.0	51.0
Antimony	632.0	34.1	74.3	40.2
Bismuth	267.0	9.0	21.0	12.0
Cadmium	321.7	18.81	31.83	13.02
Copper	1085.0	117.0	162.0	45.0
Gold		34 . 63	50.93	16.3
Iron	1450.0	300.0	369.0	69.0
Lead	326.0	11.6	15.6	4.0
Palladium	962.0	64.8	89.15	24.35
Platinum	1775.0°	75.2	102.4	27.2
Tin	. 	14.34	28.16	13.82
Zinc	420.0	45.2	67.8	22.6

¹ J. W. RICHARDS, "Metallurgical Calculations."

TOTAL HEAT CONTAINED IN CERTAIN SILICATES WHEN MELTED¹

		Melting point	Heat in solid	Heat in liquid	Latent heat of fusion
Magnesium silicate (olivine)	Mg28iO4 MgSiO3 KAlSi2O8 KAlSi2O8 CaAl2Si2O8 CaSiO3 Ca3MgSi4O12 CaMgSi2O6 Fe2SiO4 Fe2Al2Si2O12	1400° 1300° 1170° 1200° 1220° 1250° 1200° 1225° 1040° 1145°	520 403 358 360 319 344 310	528 458 460 413 444	125 83 100 100 100 94 100

In general, the specific heat of a slag (silicate) may be calculated as the mean of the specific heat of the constituents, but a quick approximation is to take it at any temperature as being

 $S_0(1 + 0.00078t)$

and over any range of temperature as being

 $S_1(1 + 0.00039[t_1 - t_2])$

where S_0 is specific heat at 0° and S_1 is specific heat at t_1 .

SOLUBILITY OF SALTS AT 10°C. AND BOILING²

One part requires for solution	Cold water	Hot water
Aluminum sulphate (+18H ₂ O)	1.052	0.088
Ammonium alum (+12H ₂ O)		0.24
Ammonium carbonate	4.0	1.5
Ammonium chloride		1.37
Ammonium chlorplatinate		80.0
Ammonium nitrate		0.19
Ammonium oxalate		2.45
Ammonium sulphate		1.026
Barium chloride (+2H ₂ O)		1.66
Barium hydrate (+8Aq)	21.32	0.02
Barium nitrate	· •	3.11
Borie acid		2.94
Bromine	` •	31.9(30°)
Cadmium chloride	1 -	0.75
Calcium carbonate	1	
Calcium chloride (fused)		0.649
Calcium hydroxide	1	
Calcium nitrate		0.28(152°
Calcium oxide		1500.0
Calcium sulphate (+2H ₂ O)		451.0
Chromic acid (CrO ₃)		
Chromic sulphate (+18H ₂ O)		
Cobaltous sulphate (+5H ₂ O)	1	
Copper sulphate (+5H ₂ O)		0.49

The table is compiled from RICHARD'S "Metallurgical Calculations."

**CREMER and BICKNELL'S "Chemical and Metallurgical Handbook."

For other tables of solubility see the table of "Properties of Compounds,"

p. 216, and "Properties of Precipitates," p. 344.

Solubility of Salts at 10°C. and Boiling. Continued

One part requires for solution	Cold water	Hot water
Copper acetate	14.28	5.05
Copper nitrate		
Copper nitrate	0.68	• • • • • • • •
Ferric chloride	0.63	0.18
Ferrous sulphate $(+7H_2O)$	1.64	0.27
Lead acetate (+3H ₂ O)	1.00(40°)	0.5
Lead chloride	105.0	20.0
Lead nitrate	2.07	0.72
Lead sulphate	12,500	<u>.</u> . <u>.</u>
Lithium chloride. Magnesium carbonate (+3H ₂ O)	1.24	0.7
Magnesium cardonate (+3H2U)	552(16°)	0.07
Magnesium chloride (+6H ₂ O)	0.6	0.27
Magnesium oxide	50,000	1 05
Magnesium sulphate crystals	3.17	1.25
Manganous chloride	1.61 0.79	0.81
Manganous sulphate (+4H ₂ O)	15.22	1.07 1.85
Mercuric chloride	8.69	1.00
Oxalic acid	244.0	16.4
Potassium alum (+12H ₂ O)	10.50	0.28
Potassium bicarbonate	3.0	0.20
Potassium bichromate	10.0	1.06
Potassium bromide	1.76	0.98
Potassium carbonate	0.91	0.64
Potassium chlorplatinate	89.3(20°)	19.3
Potassium chlorate	16.58	1.66
Potassium chloride	3.13	1.77
Potassium chromate	1.64	1.22
Potassium cyanide	0.82	• • • • • • • •
Potassium ferricyanide	2.73	1.29
Potassium ferrocyanide	3.4(15°)	1.1
Potassium hydrate	0.50	
Potassium iodide	0.7(20°)	0.5
Potassium nitrate	4.74	0.4
Potassium oxalate (acid)	40.0	10.0
Potassium permanganate	16.0(15°)	• • • • • • • • •
Potassium sulphate	10.31	3.82
Potassium sulphite		
Potassium bitartrate	250.0	9.52
Silver nitrate	0.4(19°)	0.09
Sodium acetate (+3H ₂ O)	4.0(6°) 10.0	1.7(48°)
Sodium bicarbonate	3.5	• • • • • • • • •
Sodium borate	21.5	1.82
Sodium bromide	1.13	0.87
Sodium carbonate (+10H ₂ O)	1.61	0.4(30°)
Sodium chlorate	1.0(20°)	0.49
Sodium chloride	2.78	2.53
Sodium hydrate	7 4 7	
Sodium hyposulphite (+5H ₂ O)	0.6	
Sodium nitrate	1.14(20°)	0.56
Sodium nitrate	6.7(15°)	0.4
Sodium sulphate (+10H ₂ O)	4.34	0.32(33)
Sodium sulphite	4.00	1.00
Strontium chloride	2.07	0.98
Strontium hydrate (+8H ₂ O)	55.5(20°)	2.1
Strontium nitrate	1.82	0.99
Stannous chloride	0.37	<u>.</u> . <u></u>
Tartario acid	1.31	0.50
	0.25(15°)	
Zinc chloride (+2H ₂ O)	0.23(13)	0.15

Solubilities of Solids in Water

S = number of grams of anhydrous substance which when dissolved in 100 grams of water make a saturated solution at the temperature stated.

p = number of grams of anhydrous substance per 100 grams of saturated solution.

Substance	0°C.	10	15	20	40	60	80	100
Am. chlor., NH ₄ Cl, S	29.4	33.3	35.2	37.2	45.8	55.2	65.6	77.3
Barium chlor., BaCl ₂ ·2H ₂ O, S	31.6	33.3	34.5	35.7	40.7	46.4	52.4	58.8
Barium hydrate, Ba(OH): 8H:O, S	1.67	2.48	3.23	3.89	8.22	20.04	101.4	
Bromine (liquid), Br., S		$\frac{2.48}{3.74}$	3.65	3.58	3.45	20.94	101.4	· · • • •
Cadmium sulphate.	1	0.12	0.00	0.00	0.40		1	
CdSO4.94H2O, S	76.5	76.0	76.3	76.6	78.5	83.7	70.22	60.77
Calcium hydrate,			0 180				0 004	
Ca(OH) ₂ , S	0.185	0.176	0.170	0.165	0.141	0.116	0.094	0.077
CuSO ₄ ·5H ₂ O ₃ ·S	14.3	17.4	18.8	20.7	28.5	40.0	55.0	75.0
Lithium carbonate.			10.0		-0.0	-0.0		••••
Li ₂ CO ₃ , S	1.54	1.43	1.38	1.33	1.17	1.01	0.850	0.720
Mercuric chloride,	0 50	4 50	E 00	- 40	0 00	14.0	00.1	00.0
HgCl ₂ , p Potass. chloride, KCl, S	3.50 27 8	4.5U	$\begin{array}{c} 5.00 \\ 32.4 \end{array}$	34.0	40 0	45.5	23.1 51 1	38.0 56.7
Potass. bromide, KBr, S	53.5	59.5				85.5		104.0
Potass. iodide, KI, S	127.5	136.0						
Potass. hydrate,								
KOH-2H ₂ O, S	97.0	103.0	107.0	112.0	138,03	1110	13000	178.0
Potass. nitrate, KNOs.S Silver nitrate, AgNOs, S	13.3	20.9	20.8 108 0	32.U	04.U	525 N	880 O	240.U
Sodium carbonate,	122.0	110.0	180.0	ZZZ.U	370.0	020.0	008.0	802.0
Na ₂ CO ₂ ·10H ₂ O ₃ S	7.0	12.5	16.4	21.5	46.14	46.04	45.84	45.54
Sodium chloride.								
NaCl, S	35.7	35.8	35.9	36.0	36.6	37.0	38.0	39.0
Sodium sulphate Na ₂ SO ₄ ·10H ₂ O ₅	5.0	9.0	13.4	19.4	49.05	45 05	44 05	42.0
Strontium chloride.	U.U	5. 0	10.2	10.4	₹8.U°	*U.U	**.U	72.0
SrCl ₂ ·6H ₂ O, 8	43.0	48.0	50.0	53.0	65.0	82.0	91.04	101.04

The above formulas are those of the solid phases that are in equilibrium with the solution. The figures are from SEIDELL'S "Solubilities of Inorganic and Organic Substances." D. Van Nostrand Co., New York.

¹ Very soluble in ammonium-acetate solution.
² Solid phase becomes CdSO₄·H₂O at 74°.
³ Becomes KOH·3½H₂O at 32.5° and KOH·H₂O at 50°.
⁴ Becomes Na₂CO₃·H₂O at 35°.
⁵ Becomes Na₂SO₄ at 32.38°.
⁶ Process SeClus H₂O at 70°.

⁶ Becomes SrCl₂·2H₂O at 70°.

Solvents for Metals

Gold Aqua regia.
Platinum Aqua regia.

Silver HNO₃, boiling H₂SO₄.

Lead HNO₃, boiling concen. H₂SO₄ slightly.

Mercury HNO₃, boiling H₂SO₄.

Bismuth HNO. Copper HNO. Cadmium HNO.

Arsenic Aqua regia, HNO₂ to oxide.

Antimony Aqua regia, HNO₂ to oxide.

Tin HCl, HNO₂ to oxide.

Iron HCl, dilute H₂SO₄, not by conc Aluminum HCl, HNO₃, H₂SO₄, alkalis.

Nickel HNO₃
Cobalt HNO₃
Manganese HCl.

Zinc HCl, HNO₃, H₂SO₄, alkalis.

Tungsten HNO₃ containing HF; fused KNO₂

In Dilute Solution (Fifth Normal or More Dilute)1

1. Copper is acted upon by cold dilute hydrochloric acid to a much greater extent than by sulphuric or nitric acids. Each of the last-named acids attacks the metal to about the same extent.

2. Aluminium is slowly attacked by dilute nitric acid and

sulphuric acid.

3. Lead is more rapidly attacked by hydrochloric acid than by sulphuric acid, the action of the latter acid being negligible.

4. Tin is soluble in caustic soda and in sodium carbonate

solution, but not in ammonia.

Action of Acetylene upon Metals (Chem. Zeit., 1915, 89, 42). -In acetylene installations explosions have sometimes occurred which have been attributed to the formation of explosive compounds of acetylene with the metal of the fittings. In a series of experiments it was found that pure dry acetylene in contact for 20 months with the following metals had no action upon them: zinc, tin, lead, iron, copper, nickel, brass, German silver, phosphor bronze, aluminum bronze, type metal, solder. With pure moist acetylene nickel and copper were both attacked. Unpurified moist gas, as obtained in the ordinary way from commercial carbide, had no appreciable action on tin, German silver, aluminum bronze, type metal or solder, but had a distinct action on zinc, lead, brass, much more on iron and bronze, and still more on phosphor bronze, while the action on copper was very rapid; but it is stated that in no case were explosive substances produced. It is recommended that metal fittings used in connection with acetylene should be coated with nickel or tin.

¹ A. J. Hale and H. S. Foster, Journ. Soc. Chem. Ind., May 15, 1915.

Solubility of Air in Water 1

1000 cc. of water saturated with air at 760 mm. pressure contain the following volumes of dissolved gas (calculated to volume at 0°C. and 760 mm.).

		Ten	apera	ture (of wa	ter	
	0°	5°	10°	15°	20°	25°	30°
Oxygen, cc Nitrogen, argon, etc Sum of above, cc Per cent. oxygen in dissolved air (by volume)						5.8 11.3 17.1 33.8	

SOLUBILITY OF SULPHUR DIOXIDE IN WATER (760 mm. pressure)

Temperature of water, deg. C.	20	30	40	50	60	70	80	90	100
80 ₂ , per cent. dissolved	8.6	7.4	6.1	4.9	3.7	2.6	1.7	0.9	0.0

Solubility of Gases in Water (760 mm. pressure³)

	Volumes, 0°C.	Volumes, 15°C.	Volumes, 30°C.	Volumes, 60°C.
Oxygen	0.0489 0.02388 0.03537	0.03415 0.01686 0.02543	0.02608 0.01380 0.01998	0.019 0.0100 0.015
Carbon dioxide	1.713 1300.0	1.019 802.0	0.665 598.0 28°	0.36
ArgonChlorineHelium	0.058	0.041 2.63 0.0139	0.030 1.77 0.0138	1.0
Hydrogen	0.0215	0.0188	0.018	
Hydrochloric acid	506.0	458.0	411.0	339.0
Nitrous oxide		0.74	0.63 20°	
Nitric oxide	0.074	0.0515	0.040	0.029
Sulphuretted hydrogen	4.68	3.05	$\frac{2.67}{20^{\circ}}$	
Sulphur dioxide	79.8	47.3	27.2	$\frac{18.8}{40^{\circ}}$
Acetylene		1.15 581.0 0.02045 28.4		

In the majority of the above cases the gases are in equilibrium with the water at 760° mm. pressure.

* Compiled from various authorities.

¹ KAYE and LABY'S "Chemical and Physical Constants."
² HOFMAN'S "General Metallurgy."

8 8 v.s. i-HNOs	S-aq. reg.	v.s. CH ₁ I ₁ v.s. CH ₁ I ₁ s-HCl s-HCl s-HCl s-HCl s-HCl s-HCl s-HCl s-HCl s-HCl s-HCl
1:2 3.8:100 i	00 : : 8: : : : : : : : : : : : : : : : :	
i Decomp. 1:1 871:100 v.s. s	107:100 8 v.s.	Decomp. Vols. Vols. Decomp. Decomp. i Decomp. i i i i i Decomp. Decomp. Decomp. Decomp. Decomp.
0.005:100 Decomp. 200:100 192:100 1:25 1:4 0.03:100	75:100 162:100	Decomp. 20:100 Decomp. i i i i i i i i i i i i i i i i i i i
210decomp.	Sublimes White heat	280 102.518 401 223 Sublimes Decomp. 223 Decomp. Decomp. Sublimes 220 132 63 404
Decomp. 152 Decomp. 152 Decomp.	140 Sublimes 630	93691.5 167 72 Red heat 360 Red heat 73.2 Decomp. Sublimes 130 Red heat
2.4-2.9 1.71 1.5 1.5	1.77	4. 15 4. 85 2. 67 3. 7-5.4 5. 6 3. 06 3. 06 3. 06 3. 06 3. 06 4. 71 5. 75 4. 39
245.52 1236.32 80.05 64.05 142.1 132.13 1644.26 443.98	132.15 51.12 76.12 120.2	359.96 297.50 123.22 500.96 228.6 336.61 320.4 400.75 226.58 171.66 368.47 74.96 74.96 310.27 314.72 181.34 131.96
NH, MgPO, 6H, 0 (NH,), Mo, 0, 1, 4H, 0 NH, NO, NH, NO, (NH,), 2, 0, 10, 0, 0, 3H, 0 0, 3H, 0 (NH,), PO, 10Mo- 0, 3H, 0	(NH4,) \$04 NH4HS NH4SCN Sb	SbBrs SbCls SbCls SbCls Sb2Os Sb2Os Sb2Os Sb2Os SbCls SbCls SbOCI AB AB AB ABBrs ABBrs ABBrs ABBrs
Ammonium: Magnes. phosph. Molybdate. Nitrate. Nitrite. Oxalate. Phosphate. Phospho. molyb	SulphateSulphydrateSulphocyanate	Bromide Chloride Hydride Iodide Ous chloride Ous sulphide Oxide Sulphide Oxy chloride Oxy sulphate Cryst Cryst Oxide Sulphide Arsenic: Amorp Cryst Cryst Cryst Cryst Cryst Oxide Sulphide Arenious: Bromide Chloride Fluoride Iodide

218 METALLURGISTS AND CHEMISTS' HANDBOOK

8	Formula Formula Formula 1.2H.0 H) 1.2H.0 1.2H.0 1.2H.0 1.2H.0 2.2H.0 0.4 1.3.H.0 2.1H.0 2.1H.0 2.1H.0	Mole- cular Oveight Ov	Specific gravity 3.7-3.74 3.48 3.05 3.05 3.05	Melting Point, deg. C. Bubl. 218 Subl. 218 -113 -113 Decomp. Decomp. Decomp. Decomp. Decomp. Decomp. Decomp. B12 1361 400 847	INORGANIC COM	Solubility Bolubility Water, 20°C. 3.7:100 i i i i i i i i i i i i i i i i i i	Continued Al Hot Al Al Water al	d to parts alcohol, cold o .45:100 3:100 3:100 1	Acids Acids AcidsHCI i-HCI i-HCI i-HCI s-HCI
	880s 880s 88.(PO4)s	153.37 169.37 602.19	9.4	Red heat		6 2 • • • • • • •	Becomp.		B-HCI

a l.s. in HCI	s-HNOs	8 H-WO.	v.sH ₂ SO ₄	20 02	v.s. H ₂ SO ₄ [i-dil.acids 8-conc.
red red red		3.5:100	1; 6 8 1	1: 6 8	
i i Decomp. s	85:100	Decomp.	27.5:100 16:100 i s. to 60°	61:100 i 15:10 ¹ v.s.	
i 0.002:1000 Decomp.	44:100 Decom.	Decomp. Decomp.	1:25 1:40 Decomp. Decomp. 1:1 by vol. i	0.003:1000 14:101 127:100	i 76.6:100¹ i
	Red heat 453 429	Sublimes Decomp. 80	90 17 -101	860 809 900	
Десопр.	601 600 Decomp. 271 200 225	>439 74 820 Decomp. 264	185 577 Liquid Liquid -127 2350 -25	320 571 590 Decomp. 595	Red heat
4		2.8 8.2-9.0 7-7.8	1.43 1.88 2.69 1.35 3.19	∞ 4 4 €	6.8 6.0 7.0 8.
448.82 279.67 233.44 169.44 203.53	168.94 80.02 177.23 208.0 447.76 314.38	259.02 588.76 484.11 464.0 704.21 512.21	62.02 250.76 117.38 68.00 79.92	112.40 272.24 172.40 219.36 144.42 308.48	128.40 280.53 144.47
BasP.O. BaSiF. BasO. Bas Ba(SH).	BeBrs BeCls BeSO44HsO Bi BiBrs BiCls	Bi(OH)s BiIs Bi(NOs)s·5H2O BisOs Bis(SOs)s	H.BO. Bro. BBr. BCl. BF. Br.	Cd CdBr CdCO, CdCIr·2HrO Cd(OH),	CdSO,4H,0 CdSO.4H,0 CdS
Barium: Pyrophos. Silicofluoride Sulphate Sulphydrate. Sulphydrate.		Hydrate. Iodide. Nitrate. Oxide. Sulphate. Sulphide.	dride.	III.	

	Тив Рвоеввтив	SEL 40	8 PRINCIPAL	PAL INOR	INORGANIC COM	Сомготира,	Continued	74	
		Mole-	:	Media	D : (t) .	Solubilli	Solubility (parts solid	id to parts water)	water)
Substance	Formula	cular weight O = 16	Specific	deg. C	point, deg C.	Water, 20°C	Hot	Absolute alcohol, cold	Aside
Carbonate	CarCO ₃	325.62		Denomb.		# A	V.A.	11.100	
Chloride Hydride	DH.	168 27 133 82		Decomp.		186:100 Decomp.	280:100	:::	
Nitrate Calcum Bromide	100 E	194 82 194 82 199 92	4 to 4 to 20 68 to 20 68 to	Red heat 414 810 676	Decomp.	23.100 Decomp 143:100	220:100 Decomp. 312:100	Десощр.	Decomp.
Chloride	CaCI.	130 08	F1	Decomp. 825 780		0 012:1000			
Chlorid of lime.	Carolina Car	78.07	3.15	Decomp. 902		0.03.2000		: :	• : •
Indide		293 91	2.4- 6.08	Decomp. 631	710	· .	0,08·100 230:100		eo .
	C. C. C. C. C. C. C. C. C. C. C. C. C. C	310,03	2000	2570 1866		0.008:100	0 06.100		
Carbon Tetrachloride	CCL	153.84 153.84	2.2-3.5	Decomp.	76.7		1 1680	;	<u>-</u> :
Acid.	H,CO,	62.02 44.00		. 04	: :	1:1 vol	• :	3:100	: :
Disulphide Oride Cerlum (ic) oxide.		76.14 26.00 172.25	1.29	-207	46.6	0.1:100 1:30 vols.		g a	
Chloride. Oxide. Sulphate Chloric acid.	Cect. Cerc. Cerc. So.), Hio HClo. 7Hro	246.63 328.60 586.73 210.58	38.23	9	Decomp.	16,5;100	1:200	::::	::::

Chlorine	<u>ට</u> ්ට්	35.46 52.00	5.9-6.8	-101.5 1520	-40 2200	1:2.5 vol.	1:1.4 i		s-HCl,
a page	CrOs CrsCls Crs(OH)s Cr2Os Cr2Os	100.00 316.76 206.04 152.00 716.50	2.74 2.76 5.21 1.87	190 Decomp. White heat Decomp.	Decomp. Sublimes Decomp.	165.5:100 1:1 i 120:100	ec. ec.⊶ ec	co :	Figure 19 Seal Seal Seal Seal Seal Seal Seal Seal
Chrome: Alum. Green. Orange. Yellow. Cobalt.	K,Cr(8O4),·24H,O Cr2O, PbO·PbCrO, PbCrO, Co	998.82 152.00 546.20 323.10 58.97	5.21 8.95	White heat		8.	00 क्लो क्लो क्लो क्लो		8-HN03 8-HN03
	ر دون دون دون دون دون دون دون دون دون دون	330.70 165.94	2.94	Decomp. at red heat		02 • p=4	·	;	• • • • • • • • • • • • • • • • • • • •
	CoCIs CoO CoO CoSO4.7H2O	129.89 92.99 74.97 281.15	1.84 3.6 5.7 1.92	Subl. 87		29.5:100 i 36:100¹	51:100 i i 83:100¹	1:4	
ide	CbCl, Cu	270.8	8.85-8.94	194 1083	240.5	Decomp.		: :	
Acetate	Cu(C,H,O,),H,O	199.64	:	Decomp. at 240	•	1:131	2:10	1:14	50 0
	CuCl ₂ ·2H ₂ O	170.52	2.47	498	Decomp.	7:101	103:100	⊣ 8 0	an an
Hydrate	Cu(OH), Cu(NO;), CuO CuSO4.5H;O	97.59 187.59 79.57 249.72	2.17 6.3 2.27	Decomp. 114.5 Brt. red Decomp. at	170	5:4 1:51	i v.s. 1 75:1001	» » » » » »	ගෙන නෙන
				red heat.					

¹ The anhydrous salt is referred to.

222 METALLURGISTS AND CHEMISTS' HANDBOOK

	water)	Aolde	7 1-dil. 8e.	a-HCl,	HATOH F NHOH F HNO?	1	og pp	es 10 20	S-EINO	00	* HCI	60 00	•	B. HrCO.
741	id to parts	Absolute alcohol, cold	-	óa"	# E E	-	-	¤ ± i	-	ıæ		Decomp		67
Continued	Solubility (parts solid to parts water)	Hot					l <u>ti</u>	₹ uci	· →···	612	z –	і Decomp	52.100	
POUNDS.	Solubilit	Water, 20°C		R L	1 1 1	23.100	1 3	91 100		100	% -	26,1001	22:100	13.140
мис Сом	10.00	point, deg C		1000	9.1			Red heat Sublimes		12.5				
PRINCIPAL INORGANIC COMPOUNDS.	Malain	Pount, deg. C	1035	410	Bright red 1100	}	Decomb	Sublimes 306	Decomp	47.2	Decorning	112	Degomp. at	Decomp.
		Specific		3 7	5 8 20 0 868		1 7		3 4-3 9	93	4 8-5.3	2.0	1 81	88.00
OF THE	Mole-	calar weight 0 = 16	95 64	198,00	143 14 159 21 52 00	F-4	964 42		859 06				302.15	115 84
THE PROPERTIES		Formula	Cus	Curch	0 10 10 10 10 10 10 10 10 10 10 10 10 10	Erg. SO.) y BHrO	HaOzha Au HajagSOzha	FerBra FerCu	FeatFeCaNs)1 FeatFeCaNs)1	Feet NO pr 18R20	Fer(C104)1 Fer01	Fer (FO4) 1-4 H1O Fer (SO4) 1-9 H1O	Fe(NH4),(804);	FeCO.
7		Substance		Chloride			e n sulphate		pide	Nitrate	Oxalate	ate.	Ammon sulphate	Carbonate

	to parts water)	Acids	20 A 3
q	id to part	Absolute slcohol, cold	r.s. v.s. v.s. s 11:2 i i 53:100 i i i i i i i i i i i i i i i i i i
Continued	ty (parts solid	Hot water	0.72:100 12.5:1001 17.5:100 2:1 28:1001 Decomp. 136:100 136:100 ecomp. 1 65:10 1 9:101 1 9:101 1
COMPOUNDS.	Solubility	Water, 20°C.	1.2:100 12.8:100 3:4 0.04:100 35:100 0.01:100 54:100 0.008:1000 70:100 1:15:000 1:15:100 12:100 12:100 1:50 Decomp.
	D.:1:20	point, deg. C.	Decomp. 1120 1120 1900 1900 Decomp. Subl. 322 300 349 red heat red heat
IPAL INORGANIC	Melting	point, deg. C.	695 600 Red heat 264 857 818 651 Decomp. 708 Decomp. 90 2800 Red heat 1260 Decomp. Decomp.
Princ		Specific gravity	2.11 2.3-2.4 2.3-2.4 2.24 1.74 1.75 1.75 1.91 1.91 1.14 6.2
OF THE	Mole	cular weight 0 = 16	23.5.50 23.5.50 23.5.50 23.5.50 23.5.50 23.5.50 23.5.50 25.6.32 25.6.3
Тне Ркоректиея		Formula	Lis.Cos Lichero Lichero Lis.Pos Lis.Pos Lis.Pos Lis.Pos Lis.Sos.Hso MgCos MgCo
		Substance	Lithium: Carbonate. Chloride. Hydrate. Nitrate. Sulphate. Magnesium. Ammonphos. Carbonate. Chloride. Nitrate. Oxide. Pyrophos Sulphate. Manganese. Dioxide. Manganese. Carbonate. Carbonate. Carbonate. Manganese. Manganese. Dioxide. Sulphate. Mitrate. Oxide. Sulphate. Sulphate. Nitrate. Oxide. Sulphate. Sulphate. Nitrate. Oxide. Sulphate. Sulphate. Sulphate. Oxide.

· IIIIOIOA	
s-Aq. reg. i-HCl s-HNOs s-NH,0H i-HCl s-HCl s-HCl	s s-KCN s-KCN s s s-Aq. req., idil. HCl. Explodes s-FegO4 sol. Explodes
Here He He	i i i i (1) 26:100 vol. 4.2:1vol. Decomp.
i i Decomp. 0.1:100	i 1 1 7.6:10 1 1 1.8.
i 0.002:1000 v.s. i 1.s. Decomp. i 0.2:100	62:100 i 1:2 1:3 1:3 i 0.0018:1 vol. 1.8. 5.1:100 vol. i 1.3:1 vol. Decomp. Decomp.
Sublimes 310 357.25 268 Sublimes	Explodes 71 -185.7 -153 -153 -89.4
Decomp. 400–500 290 Decomp. Decomp. Decomp 39. 38 2500 194 759 759	Sublimes 56.7 98 1.iquid -167 Explodes -101 -101 -102
13. 8. 4. 4. 6. 99 13. 6. 99 13. 6. 95 14. 4. 9. 9. 9. 9. 9. 9. 9. 9. 9. 9. 9. 9. 9.	4
232.67 472.12 655.04 298.64 497.27 200.6 96.0 283.30 144.0 144.0 192.21 58.68	129.60 110.70 92.70 280.86 90.75 90.75 253.77 120.39 30.01 44.01 46.01 76.02
Hgs HgsCls Hgsls HgsO HgsO HgsO MoCls MoOs MoOs NiCO)	Ni(OH); Ni(OH); Ni(OH); Ni(OH); Ni(OH); Ni(OH); Ni(OH); Ni(NO); Ni(NO); Ni(NO); Ni(O); Ni(O); Ni(O); Ni(O); Ni(O); Ni(O); Ni(OH); Ni(O
Mercurio: Sulphide. Chloride. Iodide. Nitrate. Oxide. Sulphate. Molybdenum. Chloride. Oxide, tri. Molybdic: Anhydride. Sulphide. Sulphide. Sulphide.	Nickelicus: Chloride Cyanide Cyanide Hydrate Nitrate Sulphide Nitrogen Chloride Dioxide Iodide Monoxide Tetroxide Trioxide Nitrio acid Nitrious acid

	Mole- cular	Specific	Melting point.	Boiling point.	Solubilit	Solubility (parts solid to parts water)	id to part	8 water)
	weight 0 = 16		deg. C.	deg. C.	Water, 20°C.	Hot water	alcohol,	Acids
080 ,	254.9 32.00	0.00143	20 -218	100	0.041			
PdCII. Pd(OH)1	177.62	• •	Sublimes		62 ·	• en	•	s s-alkalis
PdI: Pd(NOs):	•			Decomp.	Decomp.	•	• • •	
Pasovinio Pa HCio	106.7	11.4	Decomp. 85 1550 - 35	reaness 10	Decomb.		• • •	8-HNO
PH			- 133	180	. s.			• • • • • • • • • • • • • • • • • • • •
H.PO.	98.00	1.88	38.6	Decomp.	8	8	•	60 . (
	208.34	¥ :-	148	162	Decomp.	Decomp.	Decomp.	מס כ
H.PO.	82.06	i :,	22.5	Decomp.	V.8.	4.8.V	1.6.	
	_•, •	1.94	22.5 — 112	78	v.s. Decomp.	v.s. Decomp.		
P PtC14-5H ₂ O	31.04	2.1	250 changes Decomp.		. I.		V.8.	i-C8
10 T	266.12	21.5	Decomp. 1755		سره اسره	e prid e pri		8-Ao regia
Ph(C.H.O.)3H.O			00%		. 6.1	. 6	3 3.100	4
'X) [267.10	6.47	· · · · · · · · · · · · · · · · · · ·		0.001:1000	i ,		s-decomp.
PbCrO,	323.10		744	33	0.0002 per	3.3:100 i	1:20	50 0 2
Pb(OH);	•	:	Rod boot	•].s.	l.s.	•	s-alkalis
PhO:	239.10	96	Decomp.		4 4 544 4 5	र्व कल्प का	· · · · ·	
Pos(POs)2	•	: 	•	•	~	, p=4		

Plumbic;	Pbso.	303.17	6.38	937		1:22,000	v.l.s.	•#	P-NHCP
Salphide.	Pb8 K	239.17	7.5	1015	1085	i Decomp	i Decomp	Decomp	8-HNO3 Decomp
Acetate.	K,C,H,O,	137.22	•	292	•	23: 10	8:1	33:100	2
Alum.	KrAls (804) v. 24 Hr.O	• œ	1.73	84.5		11:100	22.7:100	•	
Arsenste	K.A.O.	256.28		•	•	1:0	¥ .8	4:100	•
Bicarbonate.	KHCO,	100.11		Decomp.		4:1	. 	1:1200	Decomp.
Bichromate. Bromide	KrCro,	294.2	•	7. 50 50 60	Decomp.	2:10	1:1	1:300	6 02. 6 0
Carbonate	K,CO,	138.20	2.27	838		11:10	A.8.		Decomp.
Chlorate	KCIO	122.56	•	334	Decomp.	1:14	77 	1:120	Decomb.
Chloride	KCI	•	2.0	280	Sublimes	•	1:2	1:200	i-conc. HCl
Chromate	K,CrO,	194.10	K4	940	•	63:100	79:100	· / · · · · · · · · · · · · · · · · · ·	60 (
Cysnide	KCN KCN	65.11	1.52	Red heat		`` -	122:100	0.87:100	32 80
Fluoride.	KF.2H,0	94.13	2.45	789		V.8.	V.8.	8:	Ø
Ferricyanide	Kife(CN)	329.20 429.35	 20 88	Decomp.	•	1:2.5	82:100 1:11		•
Hydrate			28	Red heat	Sublimes	112:100	311:100	-	
Todate	KIO3	214.02	3.97	580 890	•	8:100	32:100		:
Manganate	K,MnO.	197.13	9.00	ACO.		07:41	Decomp.	7:10	P.
Nitrate.	KNO,		2.08	340	Decomp.	e:	2:1	op=1 =	. .
Nitrite	KNO. K.C.O.H.O	186.11	:	Ked heat	•	 	6. 9 9. 0	~	Decomp.
Oxide	K,0		2.56	Red heat		V.B.	V .85.	V.8.	2 62
Permanganate	KMn04	158.03	2.71	Decomp.	•	1:16	1:4	Decomp.	62
Phosphate.	K,HPO,	174.25	• • • • • • • • • • • • • • • • • • • •	Decomp.	•	1:4	V.8.	V.8.	8 2
Pistinic chloride.	K.H.Sh.O.	486.16	3.90 8.00	Decomp.	•	1:100	1:19	V.L.B.	6 0
Silicate	K.SiO.	154.5		890	• • •	. c2	2 62		Decomp.
		-							

¹ Anhydrous form.

Edver: Iodide	AgI	234.80	5.67	230		0.000003;		:	i-NH.OH
Nitrate	AgNO ₈	169.80	4.35	224	Decomp.	21:10	V.B.		æ
Nitrite,	AgNOs Agreros	153.89 303.76		Dec. 134 Explodes		1:120 V.l.s.	Decomp.	1	-HNO
Oride. Peroride. Phosphate. Sulphide. Sulphide. Sulphide. Sodium. Acetate. Ammon. phosphate. Arsenite. Arsenite. Bicarbonate. Bromide. Carbonate. Carbonate. Chromate. Hydrate. Hydrate. Hydrate. Hydrate. Fodide. Nitrite. Oride.	. O. O. O. O. O. O. O. O. O. O. O. O. O.	221 22 22 23 23 23 23 23 23 23 23 23 23 23	**************************************	250 decomp. Decomp. 97 6 319 Decomp. Decomp. 710 84 818 818 820 776 776 776 776 776 776 776 776 776 77	Decomp. 742 742 White heat White heat Decomp.	1:3000 1:150 1:150 1:2 1:2 1:3 1:3 1:10	1:88 1 1:88 1 Decomp. 2:1 V.A. V.A. V.A. V.A. V.A. V.A. V.A. V.	2:100 2:100 7.1:100	P. HNO. P-HNO. P
chloride.	Na, HPO, 12H,O Na, PtCl, 6H,O	358.24 562.06	28	Десопр. 3 Десопр.		9:100i V.A.	1:11 7.8	B	1 42 10

30 METALLURGISTS AND CHEMISTS' HANDBOOK

		Mole		Maleia		Solubilit	Solubility (parts solid to parts water)	ld to parts	(water)
Substance	Formula	oular weight 0 = 16	Specific	Point, deg. C.	point, deg. C	Water, 20°C.	Hot	Absolute sleebol, cold	Acida
Sodium: Potasa, tartrate	NaKC,H.O.4H,O	281 51	1.79	75	220		,		
9					decomb.	2	3:1	:	
d. phate	NarSbrO, HrO	399.24	: .		•	4.1.e. 6:100	v.1.8. 9:10	4.l.s	: =0 :
Stannate. Bilicate	NeiShO: 4HrO	282,19	:	1020	•	61:100	62 1	:"	Decomp.
	Na.80, 10Ha0	322 23	1.49	Decomp.		1:5	1:2	 -	Arecomp.
	New Services	78.07	, o	DB .6		BJ:8T	90:100	. =	Decomp.
Stannie:	NaisOrTHO	202 18	1.56	Десошр.	:	3:41 	1:1:		Десошр .
Chloride	SaCi, HrshOr	260 84 169.02	2.28	Decomp.	114.1	Decomp.	:		P-Bride. sl-
	SuO ₂	151.00	60	1130	-	488		,	kalis i-acids
Standon.	SPEN.	183.14	:	:		eret.		:	HS'HN-
Chloride	BnCl*-2H,O H,SnO,	225.95 163 02		250 Decomp.	909	Decomp.	in expess	::	e-acida, al-
Oxychloride	SazOCk-2HtO	360 95	-			ngril se	1486-41	•	kalie. I
Bulphide	200	51.07	- 8.	970 970	0601	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	 -	: :	e-cone. HC
Bromide	S. Bra	247.47	4 4 c	630	: :	_	Decomp. 222.100	:	
CALIDODAVG	i Sign	147.08	3.6	Decomp.	:	0 001:100 0	м	:	P-HiCO
Chloride	SrClr-6R,O	286.65		832		69.1	163:1001	. :	
Nitrate	P (NO.)	211.08	2.9	Десошр .		• • • • • • • • • • • • • • • • • • •	4 00	:	a •
Oxide	SPO	103 63	3.9	3000		0.68:100	22 8 100		æ
1 Anhyderna form	the sales of								

Anhydrous form. The anhydrous salt melts at 860°C.

p-HCi Decomp. i-Cs. i-Cs.	Decomp.	s-CS ₂ i-H ₂ SO ₄ s-alkalies i-acids s-HF i-HCI s s-HNO ₂
	Decomp. Decomp. Decomp.	. oc. oc.
1:3700 Decomp.	Combines Decomp.	Decomp.
Decomp. 1:8000 Decomp. i i 305:100	Combines Decomp.	1:6 vols. Decomp. Becomp.
444.5	327 35 64 decomp.	-10 136 245 245 Decomp. 1390 1390 Red heat Decomp. Decomp.
Decomp. Decomp. 116.5 -85	10.5 14.8 Liquid Decomp.	-76 Liquid 2850 2850 211 211 Decomp. Decomp. 451 175 -48 302 272
5.46 3.7 1.98 2.0	1.842 1.97 1.62	1.68 10.78 7.28 7.28 6.25 6.25 7.1
119.63 183.70 119.70 32.07 34.09	98.09 80.07 102.99 178.16 173.91	229 55 175 50 177 55 175 50 177 55 177
8780. 8780. 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	H,SO, SO; SC! H,S;O,	H ₂ SO ₂ +Aq SO ₂ S ₂ Cl ₂ T ₃ Cl ₂ T ₃ Cl ₃ T ₃ Cl ₃ T ₃ Cl ₃ T ₄ Cl ₃ T ₆ Cl ₃
Strontium: Peroxide. Sulphate. Sulphide. Sulphur: Allotropic. Common. Sulphuretted hydrogen.	de	Sulphurous: Acid. Anhydride. Chloride. Tantalum. Tantalic: Acid. Anhydride. Fluoride. Fluoride. Tellurium.

	Тик Риоректия	OF THE		PAL INORG	PRINCIPAL INORGANIC COMPOUNDS.	POUNDS.	Continued	, 	
		Mole-		Malaine	, marken	Solubilit	Solubility (parts solid to parts water)	id to parts	water)
Substance	Formula	weight O = 16	Specific	point, deg. C.	point,	Water, 20°C.	Hot	Absolute sicohol, cold	Acids
Thallium: Ous oxide Sulphate	TLO Theo.	432.90 504.07	9	800	Decomp.	4.7:100	18:100	::	
Nitrate Oxide Tyn, see Stanum	Th(NO ₁)#12H ₂ O ThO ₂ Su	886.63 264.4 119 0	7.29	Infus 231.9	2270	é Þ.a.a	::-		E-HC
Chloride Chloride Fluoride Hydrate Onide Sulphide	1150 1150 1150 1150 1150	189 94 124.1 112.13 112.24	3.7-4.2	Liquid Decomp. 1500	9	Decomp.	Decomp.		
	H.C.	308.96 144.20 184.0		3267 275	Red heat	70		: : : : :	-H,60.
Tungstio: Aed. Anhydride Ursnium	H,WO, WO,	250.02 232.00 238.5	8- 00 60 48	Red beat	1	4 201 1-203 1-204	1 / 2 ppl		e-alkalis e-alkalis 8
Chloride	UO:	270.5	10.9	Decomp. Oxidises		₩	, apm		-cont.
Bromide Chloride Fluoride	100 m 100 m	430.34 341.42 308.5 286.5	-10	Red heat Decomp.	Decomp	320:100	. 101 170		a-other

#-HsSO4	Hallan	i-HC i-HC is a list is a l
	87:100	V.B. V.B. V.B. 1
13:10' 14.	1.1000 1.8. j 81:100 0.001:10	37:10 115:100 135:100 135:100 136:100 1
811	918	720 Red heat White heat
59.5 Decomp. 1720	658 419 3 394 Decomp.	262 Decomp. A46 Decomp. Red heat Decomp. 1050 Sublimes Sublimes Sublimes Fred.
60 . 10 to	6.0	2 91 5 4 15 6 71
502.62 516.60 302.57 605.00	182.0 100.01 225.37 125.37	25.50 25.50
UO2(NO2)2-6H2O UO2(SO4)2-8H2O U2O4 V	VrOs HVOs Zn ZnCOs	ZaCl; Zas(OH);CrOrH;O ZasFe(CN); ZasP; ZasO ZasP; ZasO;TE;O ZasP; ZasO;TE;O ZasP; ZasO;TE;O ZasP; ZasO;TE;O ZasP; ZasO;TE;O
Uranyi: Nitrate Bulphate Sulphide Uranic oxide Vanadium	Pentoxide. Vanadio acid Zinc Bromide Carbonate	Chloride Chromate Chromate Ferrocyanide Hydrate Iodide Nitrate Oxide Sulphate Sulphate Sulphate Fluoride Fluoride Nitrate Sulphate Sulphate Sulphate Sulphate Sulphate Sulphate Sulphate Sulphate Sulphate Sulphate Sulphate

The general form of this table is taken from Carmes and Bickwein's "Chemical and Metallurgical Handbook," but many more compounds have been listed, the boiling- and melting-point tables checked, and all the molecular weights recalculated by the 1915 stomic weight table on a basis of 0 = 16. Where a melting point greatly exceeding 100°C, is given for a hydrated salt, the melting point is that of the anhydrous form.

Magnetic Susceptibilities of the Elements¹

h = magnetic force.

I = intensity of magnetization.

= magnetic moment per cm.³

= pole strength per cm.²

 $B = \text{magnetic induction, or flux density} = h + 4\pi I.$

sity = $h + 4\pi I$. μ = permeability = B/h. B, h and I are in lines per cm.² and are vector quantities.

quantities.
Unit: 4π lines start from a unit magnetic pole.

$$H = \text{susceptivity} = I/h = \frac{\mu - 1}{4\pi}$$
.

Coercivity, $h_{B=0}$, is the demagnetizing force required to make B=0 after saturation.

Coercive force is the demagnetizing force required to make B = 0 after some particular field strength.

Remanence, $B_{H=0}$, is the induction remaining when the mag-

netizing force is removed after saturation.

The work done, i.e., hysteresis loss, Qe, in taking a cm. of magnetic material through a magnetic cycle between the limits

$$+ H_{\bullet} \text{ and } - H_{\bullet} = \int_{-H_{\bullet}}^{+H_{\bullet}} h dI = 1/4\pi \int_{-H_{\bullet}}^{+H_{\bullet}} h dB.$$

STEINMETZ'S empirical formula for the hysteresis loss is ηB_{mas}^n , where η is a constant and $\eta=1.6$ (usually). The magnetic properties of a material depend not only on its chemical composition, but on its previous mechanical and heat treatment; thus only general characteristics are indicated below.

Good permanent magnet steel contains about 0.5 per cent. W and 0.6 per cent. C. Cast iron, chilled from 1000°C., may also be used, but the results will never be so good as with steel. The Heusler alloys (Cu, Mn, Al) are remarkable in showing high magnetism when the components do not. With an alloy of 96.6% Fe and 3.4 Si (Yensen's alloy), the permeability rises to over 60,000 when the alloy is annealed at 1100°C.

PERMEABILITY 4

Material	h = 0.5	h = 1	h = 5	h = 20	h = 60	h = 150
Swedish wrought iron Annealed cast steel Unannealed cast steel Cast iron Magnet steel { hardened. tungsten	1450 490	3710 3500 970	2060 2100 1700 81 68 ² 80 ²	736 747 680 182 78 119	274 280 270 117 193 204	120 123 122 65 - 100 100

The figures given are only roughly comparative and can only be used as a general working guide. If exact results on particular specimens are wanted, laboratory determinations are necessary.

¹ KAYE and LABY, " Physical and Chemical Constants."

 $^{^{2}}$ At h = 15. 3 At h = 10.

Material	Coerc- ivity	Rema- nence	Η.	Hysteresis loss Qe, ergs/cm.
Swedish wrought iron	$0.97 \\ 2.08 \\ 11.0$	4,000 7,100 9,000 4,230 11,700 9,880	200 151 156 155 234 505	6,700 11,700 20,400 34,300 211,000 116,000

The figures given are only roughly comparative and can only be used as a general working guide. If exact results on particular specimens are wanted, laboratory determinations are necessary.

			tion, <i>B</i> ,			For hm	88
Material	hmas	hmas	h = 100	µmas	Coer.	Reman.	Hyst. loss, ergs/ em. ³
Mild steel,		18,190	17,700	8,350	0.6 56.0	10,300 6,400 ²	4,900
hardened at 770° Steel, 7.7% W, 1.9% C;	[[.]	• • • • •			72.0	7,0002	280,000
hardened at 800° Steel, 4% Mo, 1.2% C; hardened at 800°		• • • • •	• • • • •		85.0 85.0	4,700 ² 6,700	
Iron	50	17,100		1,750	2.21	53 % Bmas	
Silicon iron, 0.6% Si,	55	16,000	• • • • •	1,900	1.61	43 % B _{mas}	
Silicon iron, 4.5% Si,	56	15,100	• • • • •	2,500	1.21	39 % B _{mas}	
Electrolytic iron Electrolytic iron heated to 1200° C.	210	21,250	16,000	• • • • • •	18.0 2.5	10,000 12,500	
HADFIELD'S Mn steel ⁸ . Nickel, annealed	100				8.0	3,570	
Cobalt	140 114 92	10,000 8,237 2,735			12.0	3,400	19,000

The figures given are only roughly comparative and can only be used as a general working guide. If exact results on particular specimens are wanted, laboratory determinations are necessary.

$$H = I/h = \frac{\mu - 1}{4\pi}$$
, $H = 0$ for a vacuum.

The susceptibility depends very much upon the purity of the material, especially upon the absence of iron. It appears to be a periodic property of the atomic weight.

 $^{^{1}}H = 10.$

Bar magnet.

12 per cent. Mn, 1 per cent. C.

14 Mn 24, Al 16, Cu 60.

An alloy of iron and boron Fe₂B is highly magnetic, as is also MnB (16.66 per cent. B). "Trans. VIII Int. Cong. App. Chem."

Elem. solids	H × 10-4	Elem. solids	H × 10-4	Elem. solids	H × 10 ⁻⁶
Als. Sb. As. Bi. B. Cd. Cr. Cb. Cu. Au. I. Ir Fe. Pb. Mg. Mn. Mo.	+ 0.65 - 0.95 - 0.31 - 1.4 - 0.71 - 0.17 + 3.7 + 1.3(?) - 0.087 - 0.15 - 0.36 + 0.15 see p. 229 - 0.12 + 0.55 + 10.6(?) + 0.04(?)	P. Pt. K. Rh. Ru. Se. Si. Ag. Na. S. Ta. Te. Ti. Th. Sn. Ti. W.	$\begin{array}{c} -0.9 \\ +1.32 \\ +0.4 \\ +1.1 \\ +0.56 \\ -0.32 \\ -0.12 \\ -0.51 \\ -0.5 \\ +0.93 \\ -0.32 \\ -0.31 \\ +1.8 \\ +0.025 \\ +2.01 \\ +0.33 \end{array}$	U. V. Zn. Zr. Liquids; Br. Hg. N (liq.). O (liq.). H2O (15°). Gases: Air (16°). A. He. H. N. O.	$\begin{array}{c} + 0.9^{1} \\ + 1.5 \\ - 0.15 \\ - 0.45 \\ \hline - 0.41 \\ - 0.19 \\ + 0.28 \\ + 0.324 \\ - 0.80 \\ + 0.032 \\ - 0.010 \\ - 0.002 \\ - 0.008 \\ + 0.024 \\ + 0.123 \\ \end{array}$

The figures given are only roughly comparative and can only be used as a general working guide. If exact results on particular specimens are wanted, laboratory determinations are necessary.

There is a critical temperature above which magnetic permeability is very small; in the case of iron it is one of the recalescence temperatures. The critical temperature is not perfectly definite, but depends upon whether the material is being heated or cooled.

Fe, 690-895°C.; Ni, 95 per cent., 300-377°C.; magnetite, 582°C.; magnetite, 582°C.; Heusler alloys, about 300°C.; Co, 1102°C.; Cu, 72°C.; Zn, 300-350°C., possibly also at 170°C.; Sn, 18° and 161°C.; Cd, 64.9°C.

Electromagnetic Separation MAGNETIC PERMEABILITY

Iron	40,000 767 714 593	Oxide of manganese Black oxide of nickel Manganese sulphate Ferrous sulphate Nickelous oxide	167 106 100 78 35
------	-----------------------------	--	-------------------------------

The figures given are only roughly comparative and can only be used as a general working guide. If exact results on particular specimens are wanted, laboratory determinations are necessary.

Magnetic Permeability (in descending scale).

FARADAY'S arrangement.

Paramagnetic: Fe, Ni, Co, Mn, Cr, Ti, Pd, Pt, Os. Diamagnetic: Bi, Sb, Zn, Sn, Cd, Hg, Pb, Ag, Cu, As, U, Ir, W. Iron = 2000; air = 1; Bi = 0.998.

¹ Approximate only.

² Probably this paramagnetism is due to contained iron, for the more nearly chemically pure Al becomes the less its magnetism. This value is given by Honda, Annalen der Physik, 1910, p. 1045.

Action of the Wetherill Magnet on Minerals Found in Placer Sands, Together with Their Specific Gravity¹

		O120121		
Non-magnetic	Sp. gr.	Separated by current of 1/2 amp. or less		Separated by current of 3½ amp.
Mineral: Iridium Iridosmium Gold Platinum Amalgam Mercury Lead Cinnabar Galena Wolframite Cassiterite Scheelite Crocoite Columbite Pyrite Molybdenite Zircon Barite Corundum Cyanite Diamond Topaz Fluorite Apatite Spodumene Beryl	22.0 19.0 15.6-19.3 14-19 14.0 13.5 11.0 8.1 7.5 7.2-7.5 7.0 6.0 6.0 5.3-7.3 4.8 4.7 4.3-4.6 4.0 3.6 3.5 3.5 3.5 3.5 3.5 3.7	Platinum ²	Hematite 5	Platinum ² Cassiterite 7 Monazite 5
	1		Serpentine 2.5	

Minerals Which Become Quite Magnetic on Roasting³

Sulphides Oxides and carbonates oxidizing roast without reducing roast with carbon carbon Pyrite, Fe₂O₃ FeS₂ Hematite, Marcasite, Siderite, FeS_2 FeCO₂ Wolframite, Chalcopyrite, FeCuS₂ FeMnWO₄ Bornite, FeCu₃S₃ Chromite. FeCr₂O₄ Arsenopyrite, FeAsS

ZINC-IRON SEPARATION BY MAGNETIC SEPARATORS TOMBOY GOLD MINES, TELLURIDE, COLO.4

	Au,	As,	Pb, per cent.	Zn, per cent.	Fe, per cent.	Cu, per cent,	SiO ₂ , per cent.
Zinc concentrates	0.80	4.00	4.10	45.70	6.20	1.90	13.40
Iron concentrates	0.75	6.74	5.14	12.00	40.00	7.00	12.30

¹ R. H. RICHARDS, "Ore Dressing," Vol. IV.

2 Probably due to iron.

R. H. RICHARDS, "Ore Dressing," Vol. II. R. H. RICHARDS, "Ore Dressing," Vol. IV.

SHRINKAGE OF METALS¹

Metal	Casting temperature, deg. C.	Freezing point, deg. C.	Shrinkage during freezing, per cent.	Total shrinkage, per cent.
Pb	500	326	0.065	0.82
?b	600	326	0.065	0.83
n	650	416	0.08	1.40
n	700	416	0.08	1.40
n	750	416	0.08	1.40
n (Banca)	550	225	0.1-0.15	0.44
n	500	225	0,1-0.15	0.55
d	800	683		1.78
11	850	683		1.78
Zu	1250	1060	Expansion	1.42
8i	500	261		0.29
b	710	621		0.29
b	750	621		0.63
b	800	621		0.29
b	1050	621		0.66
√a²				2.57

The expansion of copper is to be attributed to the setting free of dissolved gas. The lead, zinc, copper and antimony that Wüst worked with were not even commercially pure. This may account for the inconsistency of his results with those of other authorities, given below.

SHRINKAGE OF METALS³

Metals	Percentage increase of volume on melting
Sodium	$\begin{array}{ccc} \dots & 2.5 & (a) \\ 2.5 & (b) \end{array}$
Potassium	\ldots 2.5 (a)
Tin	$egin{array}{ccc} 2.6 & (b) \ 2.8 & (a) \end{array}$
	2.8 (c)
Cadmium	4.72(c)
Lead	$\begin{array}{ccc} \dots & 3.7 & (a) \\ 3.39 & c \end{array}$
Thallium	\ldots 3.1 (a)
Zinc	; ;
Tellurium	
Antimony Bismuth	
	-3.31(c) -3.0(d)
•	-3.0 (d)

(d) C. Ludeking, Annalen der Physik, 1888, Vol. 34, p. 21.

⁽a) M. Toepler, Annalen der Physik, 1888, Vol. 34, p. 21.
(b) H. Block, Zeit. für Phys. Chem., 1912, Vol. 78, p. 385.
(c) G. VINCENTINI and D. OMODEI, Atti R. Accademia delle Scienze di Torino, 1889, Vol. 31, p. 25.

¹ From Hofman's "General Metallurgy," originally from Wist, Metallurgie, Vol. 6, 1909, p. 769.

Chem. Trade Journ., June 26, 1915.
Compilation in Engineering, Apr. 3, 1914, p. 473.

SECTION IV

CHEMICAL DATA

FUNDAMENTAL CHEMICAL LAWS

Avogadro's.—Equal volumes of all gases and vapors contain the same number of ultimate particles or molecules at the same temperature and pressure.

Conservation of Energy.—Whenever a change in mode of manifestation of energy takes place, the total amount of energy

remains a constant.

Dalton's.—See multiple proportions.

Definite Proportions.—A chemical compound always contains the same constituents in the same proportion by weight.

Diffusion of Gases.—The rate of diffusion of gases is approximately inversely proportional to the square roots of their specific gravities.

Dulong and Petit.—The product of the atomic weight and

the specific heat of the same element is a constant.

Gay-Lussac's.—When gases or vapors react on each other the volumes both of the factors and the products of the reaction always bear to each other some simple numerical ratio.

Indestructibility of Matter (Lavoisier).—Whenever a change in the composition of substances takes place, the amount of matter after the change is the same as before the change.

Mariotte's.—The volume of a gas is directly proportional to the absolute temperature and inversely proportional to the

absolute pressure upon it.

Multiple Proportions (Dalton).—If two elements A and B form several compounds with each other, and we consider any fixed mass of A, then the different masses of B which combine with the fixed mass A bear a simple ratio to one another.

Periodic.—The properties of an element are periodic functions

of the atomic weight.

The Structure of the Atom¹

The great difference between the present theory in regard to the constitution of matter and that held when most of us were students seems to make no apology necessary for introducing a short discussion of this subject here.

The nineteenth century theory of the constitution of matter postulated indivisible bodies called atoms, with properties that

¹ This short discussion is largely founded on the papers by Dr. Saul Dushman in the General Electric Review.

were repeating functions of their weights, which weights represented the proportions in multiples of which they combined with each other. The atom of hydrogen was supposed to be the smallest mass capable of existing. However, Crookes eventually showed that the cathode rays consist of negatively charged corpuscles the mass of which is less than one-thousandth that of a hydrogen atom. Later the Curies, Becquerel, Ruther-FORD and SODDY showed that the atoms of some elements were certainly unstable, and that they disintegrate spontaneously giving out negatively charged corpuscles or electrons such as constitute Crookes' cathode rays (\$\beta\$ particles), positively charged particles (α particles) of the same mass as helium atoms, and a radiation (known as γ -rays) that has since been shown to consist of X-rays of short wave-length.

It may here be noted that although the α and β rays travel with speeds comparable with that of the X-rays that the last have the power of ejecting electrons from atoms, whereas the

first two never do so.

The basis of late nineteenth century chemistry was the "socalled" periodic law of MENDELEEF, that the atomic weight of any element determines its properties, or, that the properties of the elements are periodic functions of the atomic weight. Roughly, if the elements are arranged in recurring "octaves" according to increasing atomic weights, elements of similar properties fall in columns. While this is so generally true that MENDELEEF was enabled to prophesy the discovery of certain elements with certain properties, it is not without its exceptions. For instance, according to atomic weight, iodine should come before tellurium, while according to its properties it comes after Argon and potassium form another such exceptional case. On the other hand we have elements of different atomic weights, yet inseparable chemically. These exceptions the newer theory

of "atomic numbers" attempts to explain.

Reverting to Mendelejeff's work, and considering also the elements discovered since his time, if they are arranged in order of increasing atomic weight it is observed that the first twenty elements have similar properties at every eighth element. sodium resembles lithium, phosphorus is like nitrogen and chlorine like fluorine. But beginning with argon, we must pass over 18 elements before we come to one similar to it (krypton), and then we have another group of 18 before we come to another like it, xenon. In the next series, however, comes a separate system, the rare earths, most of them so nearly alike chemically and physically that their separation is a matter of extreme difficulty. Then after another short group of normal elements come the radioactive elements, whose atoms disintegrate spontaneously in appreciable amounts in appreciable times. As said above, there are discrepancies in any arrangement by atomic weight and the view is now held that it is a so-called atomic number that is the true factor in determining the properties of the elements. In the table on p. 242, taken from the General Electric Review, are shown the elements, their atomic

weights and the atomic numbers (in brackets). What these

last are will be explained later (p. 244).

In general the members of the 0 group are inert (valency 0); those of group 1 monovalent, E₂O, EH; of group 2, divalent; etc. The members of the fifth, sixth and seventh groups possess two sorts of valences: with H they form compounds of the type EH₃, EH₂ and EH respectively, while with O, they form compounds of the type E₂O₅, EO₃ and E₂O₇ respectively. The most electropositive elements are in group 1, the most

The most electropositive elements are in group 1, the most electronegative in group 7, and in any given group, those of low atomic number are more electropositive than those of high. This property is connected with the tendency of the elements

to give out electrons.

It has been known for a long time that a heated carbon filament gives off negative electricity, which was shown by J. J. Thomson to be in the form of free electrons similar in charge and

mass to those making up cathode rays.

RICHARDSON showed that platinum and other metals give off electrons when heated and that the number of electrons emitted increases rapidly as the temperature rises. For every metal there exists a "heat of vaporization" (w) which represents the amount of work required to separate an electron from the main body. The more electropositive the metal the smaller the value of w.

For each metal there is a minimum value (V_o) of the frequency of monochromatic light which is able to cause emission of electrons from a given metal. Einstein made the hypothesis that the electron was ejected with a force hv_o where h would be a constant for all metals. h is the so-called quantum constant and since hv_o is the energy with which one electron is ejected, radiant energy must be emitted and absorbed in multiples of hv_o . The energy of the ejection of a corpuscle is independent of the intensity of the light causing the ejection, which is in accord with the above theory.

The energy of the emission of an electron may be measured by finding the potential difference V against which it is able to drive itself before coming to rest, as has been done by R. A.

MILLIKAN, for if ϵ is its charge, its energy

$$w = \frac{1}{2}mv^2 = \epsilon V = hv_0$$

The ionizing potential V, has been determined experimentally by McLennan and Henderson and is as follows:

Element	Volts	Element	Volts
Hg	4.89	Ba	2.24
Zn	4.04	Li	1.85
Cd	3.81	Na	2.11
Ca	2.94	K	1.61
8r	2.69	$\mathbf{R}\mathbf{b}$	1.56
Ca	1.39		_ · · ·

In the above table it will be noted that except for lithium and mercury, the order is the same as that of the periodic table, the most electropositive having the lowest ionizing potentials.

Mendelejeff's Periodic System of the Elements *

	Group 8 EO4		•	Fe Co Ni 55.84 58.97 56.68 (26) (27) (28)	Rh (68.	
ements)	Group 7 ErO, EH	19.0 (9)	36. (17)	Mn 54.93 (25)	79.98 (36) 	126.98 (63)
Numbers and Isotopic Radioactive Elements)	Group 6 EOs EHs	0 16.00 (8)	8.07 (91)	Cr 52.0 (24)	Se 79.2 (34) Mo 96.0 (48)	Te 137.5 (52)
d Isotopic R	Group 5 E206 EH3	14.01 (?)	81.04 (16)	V 51.0 (£3)	74.96 74.96 (33) Cb† 98.5 (41)	Sb 120.8 (61)
, ,	Group 4 EO2 EH4	12.00 (8)	Si Si (4.1)	Ti 48.1 (22)	Ge 72.5 Zr 90.8 (40)	Sn 119.0 (60) 140.25 (58)
thts, Atomi	Group 3 EsOs	B 11.00 (6)	A1.1 (13)		G9.9 69.9 (SI)	I14.8 (49)
Weig	5		1 1000	Sc (21)	Yt 89.0 (39)	1.8 1.89.0 (67)
(Containing Atomic Weights, Atomic	Group 2 EO	Be. 9 .1 (4)	Mg 24. 32 (12)	Ca 40.07 (20)	Sr (38) (38)	
(Con	Group 1 E20	H 1.008 (I) Li 6.94 (3)	Na 23.60 (11)	89.10 ((19)	Cu. 63.87 (29) S Rb (29) S 85.45 S	C _S 107.88 (47) 188.81 (66)
	Group 0	He 3 .99 (多)	Ne ₁ 20.8 Ne ₁₁ (10)	Ar 39.88 (18)	Kr 83 .93 (36)	Xe 180.2 (54)

Pt 195.8 (78)					i.
AHC H			;		listed
Ir 198.					
•		•			Numbers
(78)	1	<u> </u>			
		(88)			Atomic
	RaF F10.8	The Case	RaC: RaC: RaA: RaA:		(92) (92) figures.
W 184.0 (7.4)		(78)			UII 234.2 Ui 238.2
	Bi Ros. 0 RaE 210.2	Sai Sai	RaC 14.80		i
· 📥	2 7	₹11.5			* Iisted
Ta 181. (73)		(83)		·	• -
0 4	Pb 207.15 RaD 210.2	AcB 11.9 ThB 118.9	RaB RaB RaD: RaD:	(06)	Ux; 934 (91) weights
(68) (68) (68)	S RE		208 Rg 214 214 210	Sain a	tomic to
4 5 0		(88)		RdA 227. 228. 10	Ato
12.00 12.00 13.00	ET .0.	AoD 207.9 ThD 208.9	RaC:	(68)	19
• •	Ř		8		173
: 6. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2.		<u> </u>		Ac 257.3 MesTh:	8
		(81)		Me No	
164.8 (80) Tb 159.8 (85) Tmii (70)	Hg 800.6 (80)			(88)	ytten
160.6 (69) (64) THI (69)	64		·	AcX 223.2 ThX ThX 234.2 Ra 236.3 MesTh1	23. Ux Ux 173.6. At
	A (%)		• • • • • •		Ž.
	Au 197.2 (79)				ව ව
1				(87)	\ - ;
	<u> </u>			(86)	e Gi
•				AcEm 219.2 ThEm 220.2 RaEm 222.2	• Be = Gl. + Cb

From the facts above noted we may deduce that the electron is a constituent of all atoms, and that some atoms have a greater affinity for electrons than do others. The atoms with the lowest electron affinity are the most electropositive. There are also further considerations upon which are based calculations as to the number of electrons in the atom, some of which are discussed below.

High-frequency Spectra of the Elements

When cathode rays of low velocity strike the surface of any metal, the latter emits a continuous spectrum of X-rays with wave lengths of about 1×10^{-8} cm. The spectrum is cut off at an upper limit of frequency (V_m) which is connected with the maximum voltage of the X-ray tube by the relation.

$$\epsilon V = hV_m$$

As the voltage of the tube is raised above a definite value, the anti-cathode material emits a characteristic X-radiation classified according into three groups K, L and M. In 1913, N. G. J. Mosely measured the wave lengths of the K and L series for most elements and found that if to each element he assigned a number agreeing with its place in the periodic table (as far as Au = 79), then

$$(\sqrt{V} = a[N - N_o]$$

where V is the frequency, a and N_o are constants and N is the atomic number. According to RUTHERFORD N is the magnitude of the positive charge on the nucleus of the atom and hence must also correspond to the number of electrons in the atom, since each electron carries a negative charge and on a neutral atom the number of negative charges must equal the number of positive charges.

VARIOUS ELEMENTS, THEIR ATOMIC WEIGHTS, AND WAVE-LENGTHS OF THEIR CHARACTERISTIC X-RAYS

Element	Atomic weight	Wave-length	Remarks	
Calcium. Titanium. Vanadium. Chromium. Manganese. Iron.	48.1 51.1 52.0	3.36 × 10 ⁻⁸ cm. 3.09 × 10 ⁻⁸ cm. 2.76 × 10 ⁻⁸ cm. 2.525 × 10 ⁻⁸ cm. 2.52 × 10 ⁻⁸ cm. 2.30 × 10 ⁻⁸ cm. 2.30 × 10 ⁻⁸ cm. 2.11 × 10 ⁻⁸ cm. 2.11 × 10 ⁻⁸ cm. 1.92 × 10 ⁻⁸ cm. 1.945 × 10 ⁻⁸ cm.	Strong K radiation Weak radiation Strong K radiation Weak radiation Strong K radiation Strong K radiation Weak radiation Weak radiation Strong K radiation Weak radiation K radiation K radiation K radiation K radiation	
Cobalt	59.0 58.7	1.765×10^{-8} cm. 1.80×10^{-8} cm. 1.63×10^{-8} cm. 1.66×10^{-8} cm. 1.505×10^{-8} cm. 1.55×10^{-8} cm. 1.40×10^{-8} cm.	Weak radiation Strong K radiation Weak radiation Strong K radiation Weak radiation Strong K radiation Weak radiation weak radiation radiation	

The various constants of the electron as determined by R. A. MILLIKAN are as follows (*Proc.* Nat. Acad. Sci., vol. 3, p. 314).

The electron	e = 4.774	$\pm 0.005 \times 10^{-1}$
The Avogadro constant	N=6.062	$\pm 0.006 \times 10^{23}$
Number of gas mols. per cc. at 0°, 76 cm	n=2.705	$\pm 0.003 \times 10^{19}$
Kinetic energy of translation of a mol. at 0°.	$E_0 = 5.621$	
Change of translational mol. energy per °C	= 2.058	
Mass of an atom of H	m = 1.662	
Planck's element of action		$\pm 0.013 \times 10^{-27}$
Wien const. of spectral radiation		
Stefan-Boltzmann const. of total radiation		$\pm 0.034 \times 10^{-12}$
Grating spacing in calcite	d=3.030	± 0.001 Å
Diameter of atom, average, about		$\times 10^{-8}$
Mass of an electron	= 9.01	\times 10 ⁻²⁸

Radioactive Phenomena

The periodic table indicates that as the atom becomes more and more massive, there is a periodic recurrence of the same arrangement of the outermost electrons in the atom. observations on high frequency spectra and scattering of alpha particles lead to the conclusion that the atom consists of a positively charged nucleus of extremely small dimensions compared with those of the atom itself, and furthermore, that the chemical properties of the elements depend only upon the magnitude of the positive charge on the nucleus.1

We now pass to the discussion of observations which show us that not only is the atomic weight of but secondary significance in determining the position of an element in the periodic table and that we may have several atomic weights for the same element, but that the structure of the nucleus itself is quite

complicated.

It has already been mentioned that in the radioactive elements discovered by BECQUEREL and MME. CURIE, we have unstable atoms which disintegrate spontaneously, as has been shown conclusively by RUTHERFORD and SODDY. After a certain average period of existence, which may range from over a thousand years, as in the case of uranium (U_1) , to a millionth of a second, as in the case of RaC_1 , the atom undergoes a sudden explosion and yields an atom which possesses totally distinct properties. The disintegration is detected by the expulsion either of alpha or of beta particles.2 Accompanying the expulsion of beta particles there is also observed in a number of cases, an emission of gamma rays. These are electromagnetic pulses of extremely short wave-length (about 10⁻⁹ cm.) and are probably due to the bombardment of the atoms of the radioactive substance itself by the beta particles.

Further investigation has shown that the rate at which

these atoms disintegrate is absolutely uninfluenced by any

The diameter of the nucleus is probably less than $1_{00,000}$ the diameter of theatom, yet the nucleus contains practically the entire mass of the atom. ² The alpha particle has the same mass as an atom of helium; but differs from the latter in possessing two unit positive charges, $2E = 9.54 \times 10 E.S.U.$ The beta particles correspond in mass and electric charge to the electrons units of negative electricity, $E = 4.77 \times 10 E.S.U.$

of the factors, such as temperature, pressure, illumination with ultra-violet or X-rays, etc., which are used in controlling

the rate of ordinary chemical and physical reactions.

Since the disintegration of any atom always yields an atom occupying a different place in the periodic table we must conclude that the change actually occurs in the nucleus itself. Furthermore, as electrons and alpha particles are emitted during the disintegration, it follows that the nucleus, small as it is, consists of negatively changed corpuscles and helium nuclei, packed close together. How is it possible for positive and negative charges to remain in equilibrium under such conditions? Probably Coulomb's law fails completely for distances as small as those which exist inside the nucleus. It may indeed become reversed; that is, positive and negative charges repel each other at distances which are less than 10⁻¹³ cm.

It has been found that each of the radioactive products belongs to one of three well-defined disintegration series whose starting points are uranium, thorium, and actinium respectively. Fig. 1 illustrates diagrammatically the manner in which the

members of these series appear to be related.

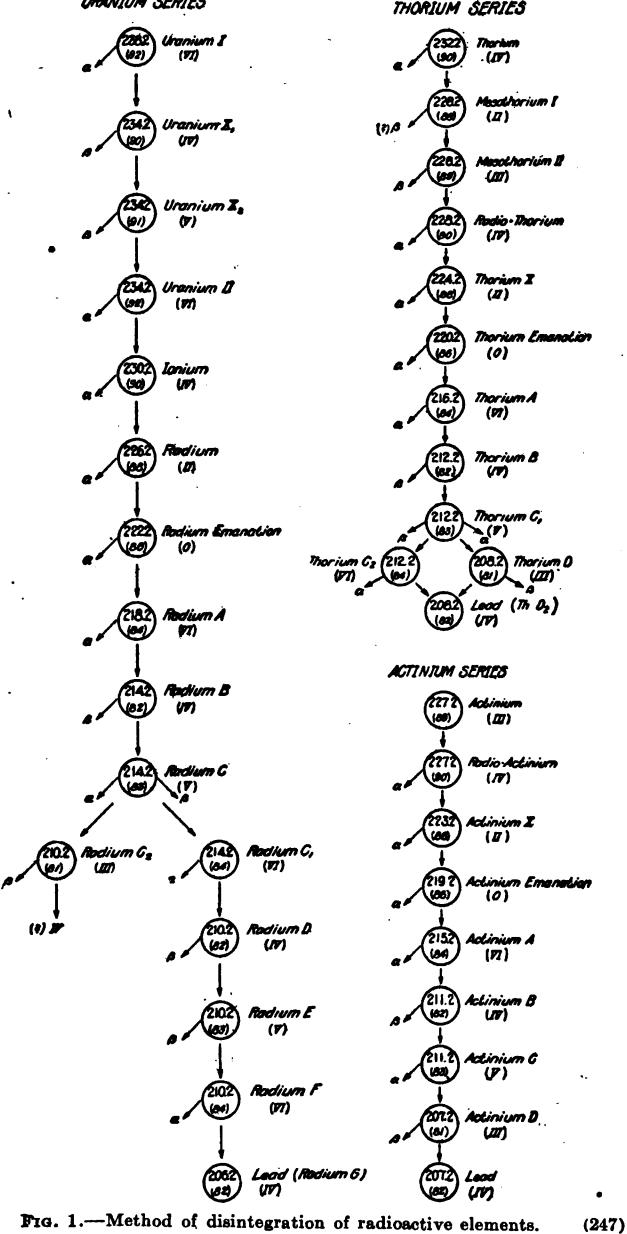
When mesothorium II disintegrates, it yields radiothorium and as a beta particle is expelled during the transformation there is no change in atomic weight. Radiothorium is chemically allied to thorium and non-separable from it. These facts lead to the conclusion that radiothorium belongs to Group IV and mesothorium II must therefore belong to Group III.

Passing to thorium X, we here again come to an element which is chemically similar to radium, thus placing it in Group II. The atom of thorium X expels an alpha particle and yields thorium emanation, a gas which is inert chemically, and condenses at low pressures between -120° C. and -150° C. The emanation resembles, therefore, the rare gases of the argon group.

Thorium emanation is the first member of the group of transformation products that constitute the thorium "active deposit." They are indicated in Fig. 1 as thorium A, B, C_1 , C_2

and D.

The most noteworthy feature about these products is the fact that individual members of each series appear to be chemically indistinguishable from certain members of the other series. Owing, however, to the difference in previous history of these atoms, they possess different atomic weights and also differ in period of existence. In other words, we have here cases of elements that are absolutely inseparable by all chemical methods so far devised, and yet differ in that respect which has hitherto been taken to be the most important characteristic of an element—its atomic weight. Soddy, who has drawn attention to these cases, has named these products isotopes, since they occupy the same place in the periodic table. As shown in the table in Fig. 1, there are three other isotopes of thallium, and no less than six isotopes of lead. These results are thus in accord with the conclusion already advanced above,



URANIUM SERIES

Fig. 1.—Method of disintegration of radioactive elements.

that the most characteristic property of any element is its atomic number, and not the atomic weight. The different isotopes of any element may therefore be regarded as consisting of atoms which are all alike as far as the number of electrons, their arrangement, and the charge on the nucleus; but the arrangement of electrons and alpha particles in the nucleus of each of these atoms is evidently not the same. Hence arise the differences in mass and average life.

Soddy's Law of Sequence of Changes.—A comprehensive survey of the chemical properties of the different radioactive elements has led Soddy and Fajans independently to an interesting and extremely important generalization which enables them to assign these isotopes to their places in the Periodic Table.

It will be remembered that an alpha particle is a helium atom with two positive charges. By its expulsion, therefore, the atom must lose two positive charges, and the atomic weight must decrease by four units. Similarly, the expulsion of a beta particle means the loss of a negative charge or, what is equivalent, the gain of one positive charge; and since the mass of the beta particle is extremely small compared with that of the atom, there is practically no decrease in atomic weight. Now in the Periodic Table the valency for oxygen, an electronegative element, increases regularly as we pass from Group 0 to Group VIII, while that for hydrogen, an electropositive element, decreases, i.e., the electropositive characteristic increases by one unit for each change in the group number as we pass in any series from left to right. Furthermore, in each group the electropositive character increases regularly with increasing atomic weight.

These considerations led Soddy and Fajans to this conclusion:

The expulsion of an alpha particle from any radioactive element leads to an element which is two places lower in the Periodic Table (and has an atomic weight which is four units less) while the emission of a beta particle leads to an element which is one place

higher up, but has the same atomic weight.

It is possible, therefore, to have elements of the same atomic weight but possessing distinctly different chemical properties, and, on the other hand, since the effect of the emission of one alpha particle may be neutralized by the subsequent emission of two beta particles, it is possible to have two elements which differ in atomic weight by four units (or some multiple of four)

and yet exhibit chemically similar properties.

As an illustration, let us consider the Uranium Series. Uranium I belongs to Group VI. By the expulsion of an alpha particle we obtain uranium X_1 , an element of Group IV. This atom in turn disintegrates with the expulsion of a beta particle. Consequently uranium X_2 must belong to Group V. In this manner we can follow the individual changes that lead to the different members of the series, and by means of the generalization of Soddy and Fajans we cannot only assign to each element

its place in the Periodic Table but also its atomic weight, as has

been done in Fig. 1.

This generalization has been of material assistance in elucidating some of the difficult problems in the study of the disintegration series. More than this, it has led to the intensely interesting conclusion that the end product of each of the three radioactive series in an isotope of lead. The results of the most recent work on the atomic weight of lead are in splendid accord with this deduction, as it has been found that lead which is of radioactive origin, has a slightly lower atomic weight than ordinary lead.¹

In a couple of cases the isotope has not been definitely isolated, but there can hardly be any doubt of its existence. Thus, the disintegration product of radium C_2 must be an element of Group IV, but the evidence for its existence is very

meager.

General Conclusions Regarding the Structure of Atoms

It is obvious that any theory of the structure of the atom which we can form at present must be regarded as only a first approximation. But there are some conclusions which can be drawn with a certain degree of assurance from the above observations:

Firstly, the atom must be constituted of a positive nucleus of extremely small dimensions (but approximately equal in mass to the atom itself), and a number of electrons distributed presumably in one or more rings or spherical shells outside the nucleus, the total number of electrons being equal to the positive charge on the latter. Secondly, all the physical and chemical properties of the atom (excepting radioactive and gravitational) are governed solely by the magnitude of this charge on the

nucleus (or atomic number).

Thirdly, in order to explain chemical combination and periodic properties, we must assume that there are two classes of electrons, an inner and outer set. The outer ones are the electrons which are active in chemical combination and conduction of electricity through metals. They are the so-called valency electrons. The number of electrons in this outer set undergoes periodic changes in value as the atomic charge increases, and the maximum number of electrons which are stable on the outer surface of the atom is eight, thus accounting for the periodicity of eight in Mendeljeff's table.

The outer electrons are also those which are active in the production of ordinary emission spectra. If Lorentz's explanation of the Zeeman effect is right, and it is the only one that explains the phenomenon quantitatively, then we must conclude that the lines visible in ordinary emission spectra are due to the vibration of electrons with frequencies ranging around 10¹⁵ per second. The fact that these emission spectra are modified by method of excitation and also differ with different compounds, shows that the electrons producing these phenom-

1J. Am. Chem. Soc., 36, 1329, 1914.

ena are near the surface of the atom and therefore probably

the same as the valency electrons.

On the other hand, the inner electrons are unaffected by ordinary methods, but high velocity electrons may stimulate them and thus produce the high-frequency spectra observed by Moseley and others. As pointed out by Kossel the continuity of the K-line spectra for the different elements from the lowest atomic number to the highest, shows that the periodicity observed in the outer electrons does not extend to the innermost.

C. A. Kraus has stated the reasons for drawing the same conclusions from a chemical standpoint. "The outer electrons," he writes, are held loosely and are able to move from atom to atom. These electrons are very sensitive to changes in condition, such as temperature, pressure, the presence of other atoms, etc. So weak is the bond emitting the electron to an atom, that more electro-negative atoms may remove it from the original atom in question. The electrons to which conduction is due in metals are the same electrons which are involved in the common chemical combinations of metals with other elements.

"The less tendency the metal has to retain its electron, the more electro-positive it becomes and the more readily does it in general react. Ordinarily, the positive and negative constituents of a compound are held together through the medium of the electron. Under certain conditions, however (for example in solution in a dielectric medium) the electrostatic force acting between the metallic atom and its electron becomes weakened to such an extent that the negative constituent escapes, carrying the electron with it. The same result may be obtained at high temperatures with the fused salt or even with the solid compound."

That is, when sodium and chlorine combine, the sodium atom gives up an electron to the atom of chlorine (which is the electro-negative element), and the atoms are thus held together by the electrostatic forces between the positively charged residue of the sodium atom and the negatively charged atom of chlorine. In a solution of high dielectric constant such as water, these electrostatic forces are weakened to such an extent that we have the phenomenon known as "dissociation" and the formation of Na (sodium ion) and Cl (chlorine ion). Naturally the properties of those ions are radically different from those of metallic Na and gaseous Cl2 as we know them.

Sodium sulphite (Na ₂ SO ₃)	20 g.
Sodium bisulphite (HNaSO ₂)	20 g.
Cupric acetate (Cu·2C ₂ H ₂ O ₂ ·H ₂ O)	20 g. 20 g.

The electrolytic conductivity of metallic lithium dissolved in liquid ammonia is explained in a similar manner. Here we actually have a separation of the lithium atom into Li and an electron, and in the electrolysis, the lithium is deposited at the cathode while electrons are carried to the anode.

Similar ideas have been expressed by Sir Wm. Ramsay; G. N. Lewis; W. Kossel and others. All are agreed upon this conclusion that chemical combination between different atoms consists in the transference of one of the outer electrons from one atom to the other. But as to the actual distribution of the electrons in the different atoms and the nature of the forces between the electrons and the positive nucleus—regarding these and allied questions there is quite a variation of opinion.

THE PERIODIC TABLE OF THE ELEMENTS

Series	Zero group	Group I R ₂ O	Group II RO	Group III R2O3	Group IV RH4 RO2
1 2 3 4 5 6 7 8 9 10 11	Ne = 20.0 Ar = 39.88 Kr = 82.92 Xe = 130.2	(Cu) = 63.57	Be = 9.1 Mg = 24.32 Ca = 40.07 Zn = 65.37 Sr = 87.63 Cd = 112.4 Ba = 137.37	Al = 27.1 Sc = 44.1 Ga = 69.9 Yt = 88.7 In = 114.8	C = 12 Si = 28.3 Ti = 48.1 Ge = 72.5 Zr = 90.6 Sn = 119 Ce = 140.25 Pb = 207.1 Th = 232.4

Series	Group V RH: R ₂ O ₅	Group VI RH ₂ RO ₃	Group VII RH, R ₂ O ₇	Group VIII RO4
1 2 3 4 • 5 6 7 8 9 10 11 12	P = 31.04	8 = 32.07 $Cr = 52.0$	Br = 79.92 = 100.0	$\begin{cases} Fe = 55.84, Ni = 58.68 \\ Co = 58.97, Cu = 63.57 \end{cases}$ $\begin{cases} Rh = 102.9, Ru = 101.7 \\ Pd = 106.7, Ag = 107.88 \end{cases}$ $\begin{cases} Ir = 193.1, Pt = 195.2 \\ Os = 190.9, Au = 196.7 \end{cases}$

Examples of the manner in which the properties of the elements are progressive functions of the atomic weight are shown in the tables of the Ca-Sr-Ba, and Fl-Cl-Br-I families which follow:

Element	Calcium	Strontium	Barium
Atomic mass Specific gravity Carbonate disso-	40 1.6	88 2.5	137 3.6
ciates; temperature	600C.	1100°C.	1400°C.
liter of water at 15°C	1.32	18	50
Heat of formation of chloride; units.	170	185	195

Element	Fluorine	Chlorine	Bromine	Iodine
Atomic mass Boiling tempera-	19	35.5	80	127
ture	- 187°C 1.15 (liquid)	-33° 1.5 (liquid)	59° 3.2 (liquid)	184° 5 (solid)
Union with hydro- gen takes place.	In the dark at ordinary tempera-tures.	In sunlight.	At red heat.	At red heat but incom- pletely.
Heat of formation of hydrogen compound.	37.6 heat	22	8	-6.1
Stability of hydro- gen compound	Most stable.	Decomposed at 1500°C.	Decomposed at 800°C.	Decomposed at 180°C.

ELECTROCHEMICAL EQUIVALENTS¹

Element	Valence	Atomic weight	Electrochemical equivalent (1 amp. 1 sec.)	
M +	3	27.1	0.00009363	
\g +	1	107.88	0.0011183	
$\mathbf{Br} - \dots$	1	79.92	0.00082845	
$2d + \dots$	$egin{array}{c} 1 \\ 2 \\ 2 \end{array}$	112.40	0.00058257	
Ca +	${f 2}$	40.0	0.00020732	
$1 - \dots$	1	35.46	0.00036758	
$c_0 + \dots$	$\begin{array}{c} 1 \\ 2 \\ 2 \end{array}$	58.97	0.00030564	
$\mathbf{u} + \dots$	2	63.57	0.00032948	
Cu +	$egin{array}{c} 1 \\ 2 \\ 4 \end{array}$	63.57	0.00065897	
$n + \dots$	${f 2}$	119.0	0.00061678	
$\mathbf{n} + \dots$	4	119.0	0.00030839	
re +	${f 2}$	55.84	0.00028947	
re +	$egin{array}{c} 2 \\ 3 \end{array}$	55.84	0.00019267	
ا ا	1	19.0	0.00019695	
I +	1 ·	1.008	0.000010449	
	1	126.92	0.00131566	
Ig +	$egin{array}{c} 1 \\ 2 \end{array}$	200.6	0.00103661	
Ig +	1	200.6	0.00207322	
$V_1 + \dots$	1 2 3 2 4 2	58.68	0.00030414	
lu +	3	197.2	0.00068139	
) –	$oldsymbol{2}$	16.00	0.000082928	
Pt +	4	195.2	0.00050584	
²t +	$ar{2}$	195.2	0.00101168	
'b +	$ar{f 2}$.	207.1	0.00107340	
ζ +	1	39.10	0.00040531	
√a +	ī	23.00	0.00023842	
n +	$ar{f 2}$	65.37	0.00033881	
В +	$\ddot{3}$	120.2	0.00041532	
i +	$\frac{3}{1}$	6.94	0.00007245	
Mg +		24.32	0.00011567	
$\tilde{\mathbf{M}}\mathbf{n}+\dots$	2 3 2 2	54.93	0.0001891	
i -	$oldsymbol{\check{2}}$	28.3	0.0001449	
3	$ar{ar{2}}$	32.07	0.0001656	

¹Gore, "The Art of Electrolytic Separation of the Metals."

INTERNATIONAL ATOMIC WEIGHTS, 1916.

	INTERN	ATIONAL	ATOM	IIC MEIGH	15, 1510.	
Element	Symbol	Weight	Val- ence ¹	Electro- chem. equi- valents, g. per amp hr.	Melting points	Boiling points
Aluminum Antimony Argon Arsenic Barium	Al Sb A As Ba	27.1 120.2 39.88 74.96 137.37	3 3 0 3 2	0.8368 1.4966 0.9324 2.5619	658.7 630.0 -188.0 850.0 850.0	1800.0 1460.0 -186.0 450.0 ²
Bismuth Boron Bromine Cadmium Caesium	Bi B Br Cd Cs	208.0 11.0 79.92 112.40 132.81	3 1 2 1	2.5854 2.9814 2.0955	271.0 2350.0 -7.3 320.9 26.0	1440.0 58.75 778.0
Calcium Carbon Cerium Chlorine Chromium	Ca Cc Cl Cr	40.07 12.05 140.25 35.46 52.0	2 4 4 1 3	0.7477 0.1118 1.3220 0.6476	810.0 >3600.0 .623.0 -101.5 1520 to>Fe	- 37.6 2200.0
Cobalt Columbium. Copper Dysprosium. Erbium	Co Cb Cu Dy Er	58.97 93.1 63.57 162.5 167.7	2 5 2	1.1000	1610* 1950–2200 1083.0	2100.0
Europium Fluorine Gadolinium. Gallium Germanium	Eu F Gd Ga Ge	152.0 19.0 157.3 69.9 72.5	1	0.7085	-223.0 30.1 958.0	-187.0
Glucinum Gold Helium Holmium Hydrogen	Gl Au He Ho H	9.1 197.2 4.002 163.5 1.008		2.4513 0.03759	1800.0 1063.0 -271.9	-268.8 -252.8
Indium Iodine Iridium Iron Krypton	In I Ir Fe Kr	114.8 126.92 193.1 55.84 82.92	1 4 2	4.7803	$ \begin{array}{c} 154.5 \\ 114.0 \\ 2300.0 \\ 1530 \pm 5 \\ -169.0 \end{array} $	184.35 2450.0 -151.7
Lanthanum. Lead Lithium Lutecium Magnesium.	La Pb Li Lu Mg	139.0 207.20 6.94 175.0 24.32	2 1 2	3.8613 0.2622 0.4531	810.0 327.4 186.0	1525.0 1120.0
Manganese. Mercury Molybde- num Neodymium Neon	Mn Hg Mo Nd Ne	54.93 200.6 96.0 144.3 20.0	2 2 2 0	1.0255 7.4803 1.7900	$1260 \pm 20 \\ -38.7$ 2500.0 840.0 -253.0	1900.0 357.0

¹In those cases in which a metal has two valences, the valence given corresponds to the electrochemical equivalent, and may not necessarily be the commoner one.

* Sublimes. * Commercial metal, about 1480° C.

International Atomic Weights, 1916. Continued

					<u> </u>	
Element	Symbol	Weight	Val- ence ¹	Electro- chem. equi- valents, g. per amp hr.		Boiling points
Nickel Niton	Ni Nt	58.68 222.4	2 0	1.0945	1452 ± 3	
Nitrogen	N Os	14.01 190.9	3	0.1745	-210.5 2700.0	-195.7
Oxygen	Õ	16.00	2	0.2983	-218.0	-183.0
Palladium Phosphorus Platinum	Pd P Pt	106.7 31.04 195.2	24	1.9951 1.8206	1550.0 44.1 1755.0	287.0
Potassium Praseody-	K Pr	39.10	1	1.4584	62.3	667.0
mium		140.9		• • • • • • • •	.940.0	• • • • • •
Radium Rhodium	Ra Rh	226.0 102.9	2		900.0 1940.0	• • • • • • • •
Rubidium	Rb	85.45			38.0	• • • • • • •
Ruthenium . Samarium	Ru Sa	101.7 150.4		• • • • • • • • • •	>1950.0 1350.0	• • • • • • •
Scandium Selenium Silicon	Sc Se Si	44.1 79.2 28.3	2 4	1.477 0.2638	1200.0(?) 218.5 1420.0	690.0
Silver Sodium	Ag Na	107.88 23.00	1	4.0248 0.8596	961.0 97.5	1955.0 742.0
Strontium Sulphur Tantalum	Sr S Ta	87.63 32.06 181.5	2 2	1.6333 0.5980	>805, 850 < >Ca < Ba 116.5 2850.0	444.5 1390.0
Tellurium Terbium	Te Tb	127.5 159.2	2	2.379	451.0	1390.0
Thallium	Tl Th	204.0 232.4			302.0 >1700.0 <pt< td=""><td>1700.0</td></pt<>	1700.0
Thulium	Tm Sn	168.5 118.7		2.2188	991 0	2270.0
Tin Titanium	Ti	48.1	2 4	0.4490	231.9 1795.0±15.0	2210.0
Tungsten Uranium	WU	184.0 238.2	6	1.1437	3267 Near Mo.	• • • • • • •
Vanadium	V	51.0			1720.0 ± 20.0	
XenonYtterbium	Xe Yb	130.2 173.5	0		-140.0 $1800.0(?)$	-109.0
Yttrium Zinc Zirconium	Yt Zn Zr	88.7 65.37 90.6	· · · · · · · · ·	1.2194	1200.0(?) 419.3 2350.0(?)	918.0

Note.—In addition to the above elements, there is some reason to believe in the existence of a gas "coronium" (so called from its existence in the solar corona) which would form 0.00058 per cent. of the earth's atmosphere according to Dr. A. Wegener's calculations (Science, Oct. 31, 1913).

In those cases in which a metal has two valences, the valence given corresponds to the electrochemical equivalent, and may not necessarily be the

commoner one.

A SHORT ACCOUNT OF THE COMMON ELEMENTS.1

Aluminum.—Atomic weight, 27.1; trivalent; sp. gr., cast, 2.56; rolled, 2.66. A silver-white metal; breaks with crystalline fracture. Melts at 657°C.; volatilizes at a very high temperature; specific heat from 0° to 100°C., 0.2270 (mean); latent heat of fusion, 100 cal.; coefficient of linear expansion, 0.0000231; heat conductivity, 31.33 (Ag = 100). Is friable at 530°C. The tensile strength of cast aluminum is about 15,000 lb. per sq. in., but this may be increased by drawing to 35,000 lb. per sq. in. Its conductivity is about 58 (Ag = 100).

The metal cannot be reduced with carbon; but forms a carbide Al_4C_3 ; and a nitride AlN. It is reduced by sodium from its compounds. Said to be paramagnetic, susceptibility 0.6×10^{-6} . Is very malleable between 100° and 150°C. Is notable for the lightness of its alloys, and for its energetic reduction of oxides of other metals (thermit process). It cannot be produced by direct electrolysis in aqueous solution but is deposited electrolytically from a solution of its oxide in cryolite. The

oxide forms the base of most artificial gems.

Antimony.—Atomic weight, 120.2; trivalent usually; sp. gr. 6.71; melts at 632°F., and volatilizes at about 1,500°C. Is in no degree malleable or ductile; its electric conductivity is 4.2 (Ag = 100). Has extremely crystalline structure; coefficient of linear expansion, along axis 0.0000168; normal to axis 0.0000089. It may readily be crushed to powder. Hydrochloric acid has a slight solvent action on it; nitric acid converts it to the pentoxide; sulphuric acid first oxidizes it and then converts it to sulphate. Chlorine reacts directly with the metal, forming anhydrous chloride. The classic process for the recovery of antimony is its liquation as sulphide, Sb₂S₃, from rich ores and the subsequent throwing down of the antimony by melting with scrap iron. It is also recovered by subjecting the ore to an oxidizing roast, driving off the antimony in fume, which is caught and reduced to metal. mony can also be recovered by lixiviation of the ores with sodium sulphide, obtaining either Na₃SbS₃ or Na₃SbS₄. From these solutions it can be regained either chemically or by electrolysis. Another important source of antimony is in refining argentiferous lead. Before mixing in zinc for the Pattinson process the lead is oxidized slowly for some time to purify it (softening process). The slag thus formed runs high in antimony from which it is recovered as antimonial lead.

In refining crude antimony (not hard lead) the crude metal is fused with 8 to 12 per cent. of Sb₂S₃ and 4 to 5 per cent. of NaCl to bring it up to 98 to 99 per cent., and then it is given a final purifying by "starring," in which it is melted in the presence of Sb₂S₃ and soda ash. No iron must be allowed to get into it during this process; so the iron ladles, etc., are

kept well covered with whitewash.

Argon.—Occurs in the air to the extent of 0.935 per cent.

¹ For the ordinary properties, see the preceding table.

It can be prepared by passing atmospheric nitrogen, free from oxygen and moisture, over red-hot magnesium ribbon; magnesium nitride is thus formed while the argon does not combine.

Arsenic.—Atomic weight 74.96; trivalent usually; sp. gr., crystalline 5.73, amorphous 4.71; a brittle steel-colored metal, volatilizes at 450°C., without melting. The metal and the pentavalent compounds are not poisonous, but the metal easily oxidizes and the pentavalent form easily reduces to the extremely poisonous trivalent form. Forms a very volatile hydride AsH₃, which serves as the basis for the famous Marsh test. Most of the arsenic on the market is recovered from flue dust, in which the arsenic concentrates. This is roasted in reverberatories and the roasted arsenious oxide condensed in large chambers.

Barium.—The properties of this metal are still in doubt, as it is probable that it has not yet been prepared in a high degree of purity. The impure form is prepared by reducing the oxide with magnesium. The peroxide, BaO₂, formed by heating BaO to 500°C. in the presence of air, serves as the basis of hydrogen peroxide manufacture. At a still higher tempera-

ture it again gives off oxygen.

Beryllium.—Atomic weight, 9.1; bivalent; sp. gr. 1.842. A hard, lustrous, white, malleable metal. Melts at 1278°C. Does not volatilize at 1900°C. Hardness, over 6. Burns like magnesium when in powder or ribbon. Withstands water better than magnesium, but this apparent inertness may be due to a film of oxide. Prepared by electrolyzing a mixture of sodium and beryllium fluorides, or by decomposition of the fluoride by sodium, potassium or magnesium. Has highest heat of fusion of any metal, 277 cal. Derives its former name, glucinum, from

the sweetish taste of its compounds.

Bismuth.—Atomic weight, 208; trivalent; sp. gr., 9.80; the metal is neither malleable nor ductile; it melts at 266°C. and volatilizes between 1100 and 1450°. Electric conductivity, 1.3 (Ag = 100). This metal is remarkable in that it expands on solidifying; its sp. gr. is about 10.055 just above the melting point. It is the most diamagnetic material known. Is obtained: (1) by liquation in crucibles or retorts of ores carrying native bismuth; (2) by reduction processes, using Na₂CO₃ as a flux, beside CaO and FeO, since the fusion temperature of the slag must be low; (3) as a by-product of electrolytic lead refining; (4) as a by-product of steam Pattinsonizing (Hulst process); (5) as a result of the wet treatment of the last oxide coming from the cupellation of lead-silver bullion. Some of its alloys melt at remarkably low temperatures (see fusible metals under "alloys").

Boron.—The element is found in nature as boric acid and borax. It is obtained by reduction as a brown amorphous powder, which, on dissolving in molten aluminum, separates on cooling in crystalline form, said to rival the diamond in hardness. The suboxide is an energetic deoxidizer, recommended by Weintraub for insuring high-conductivity copper castings.

Bromine.—Occurs in the mother liquors of certain salt-wells in the United States and at Stassfurt, Germany. It is liberated from these liquors by the action of chlorine, or by direct electrolysis. It is, at ordinary temperatures, a fuming red liquid of unbearable odor, from which it takes its name. It is more active than iodine and less than chlorine.

Cadmium.—Atomic weight, 112.4; always bivalent; sp. gr., cast, 8.60; white metal of bluish tinge, intermediate in hardness between tin and zinc. Melts at 320°C.; boils at 778°C., so can be separated from zinc by volatilization. Is precipitated from solution by zinc. Is remarkable for its fusible alloys: thus, 2 parts Bi, 1 part Sn, 1 part Pb melt at 93.75°C.; but with 10 per cent. Cd added melt at 75°C., while Cd 14.3, Sn 19.0, Pb 33.1 and Bi 33.6 melt at 66°C. Its metallurgy is simply that of a by-product of zinc. It is greatly concentrated in the first zinc dust formed in roasting the ores. The cadmium may then be freed from the zinc in a wet way owing to the fact that if a mixture of cadmium and zinc oxides be treated with insufficient sulphuric acid to dissolve both, the cadmium will be dissolved before the zinc will. Moreover, if a mixture of cadmium and zinc sulphates be agitated with a mixture of cadmium and zinc oxides, the cadmium will be dissolved and zinc oxide will be precipitated. It is eventually freed from the last zinc by electrolysis, if a very pure metal be desired. If this is not necessary, advantage is simply taken of the fact mentioned above, that CdO is more velatile than ZnO, and also that CdO reduces at a lower temperature than does ZnO, and that CdO precipitates Zn from ZnSO₄ as ZnO.

Cæsium.—Of no commercial value. Atomic weight, 132.8. Discovered by Kirchoff in the Dürkheim mineral water. Its spectrum contains two characteristic blue lines, whence its

name.

Calcium.—Atomic weight, 40.07; bivalent; sp. gr., 1.85. A lustrous, silvery-white brittle metal. It is less malleable than the alkali metals; shows a crystalline fracture. It melts in vacuo at 760°C. It forms a hydride, CaH₂; a nitride, Ca₈N₂ and a carbide, CaC₂. It is a powerful deoxidizer. Cannot be reduced by carbon. The metal can be cut with a knife and

will scratch lead but not calc spar.

Cerium.—Atomic weight, 140.25; sp. gr., 6.73. It has an iron-gray color, is soft, being somewhat harder than lead, is malleable and easily rolled. Fuses at about 800°C. Its most remarkable property is that of combining with heavy metals, such as iron or copper, to form dense but easily oxidizable alloys (the pyrophoric alloys). Fine wire made from the metal burns with a brilliancy even exceeding that of magnesium. It dissolves easily in dilute acids, but only to a limited extent in cold concentrated sulphuric or nitric acid. It will reduce the oxides of most metals or metalloids. On filing or scraping cerium with a knife, the filings or scrapings will take fire. It can be prepared by fusion of the anhydrous chloride, but not by direct reduction of its oxide by carbon, as a carbide is

formed. Lanthanum, præseodymium and neodymium greatly resemble it. Cerium fluoride is used in the "flaming-arc" lamp.

Chlorine.—Atomic weight, 35.46. Gas at ordinary temperatures. It derives its name from its greenish-yellow color. Strongly corrosive to organic tissues as well as to most metals. A violent poison. Liquefies readily. It is much used in commerce as a bleaching material, for which it is derived by the Weldon process (q.v.), or by electrolysis of sodium chloride solutions (Castner-Kellner, Gibbs process, etc.). The hypochlorites form the basis for many disinfectants; the chlorates form the basis of many modern explosives.

Chromium.—A bright gray, very lustrous, very hard crystalline metal. Atomic weight, 52.0; sp. gr., 6-7. It oxidizes slowly in cold air, readily on heating. Does not burn so readily as iron on heating in oxygen. Combines readily with the

halogens, sulphur, silicon and carbon.

down first.

Chrome-iron ore can be directly smelted with carbon to give ferrochrome. To obtain pure chromium the chrome-iron ore is roasted with sodium carbonate or sodium carbonate and lime. The mass should not be fused. From this sintered mass sodium chromate can be leached out. If H₂SO₄ is added to sodium-chromate solutions the bichromate is produced. Sodium bichromate can be reduced with sulphur to give chromous anhydride, which can then be reduced with carbon or with aluminum. In the carbon reduction the metal is not fused, but remains as a powder. Chromium alloys readily with iron, manganese, cobalt and tungsten; with other metals only with difficulty. It can also be prepared by aluminum reduction.

Cobalt.—Atomic weight, 58.97; trivalent; sp. gr. 8.66-8.92. A silver-white metal, melts at 1610°C. if pure. Yield point, 31,200-65,600 lb. per sq. in. Specific heat, 0.1056 (15°-100°). This is the most magnetic element except iron. Exceeds iron both in hardness and tenacity. May be turned with ordinary lathe tools. Brinnell hardness, chilled from melting point, 90.8; annealed from 250°C., 77.3. Cobalt may be separated from nickel when both are in solution by precipitation with milk of lime or with calcium hypochlorite; the cobalt comes

Copper.—Atomic weight, 63.57. The only red metal. Bivalent. Tough; ductile. The best conductor of electricity (except perhaps silver); the third best conductor of heat. Recovery of copper is chiefly by smelting sulphide ores to give a copper-iron sulphide, the earthy materials forming a fusible slag, then blowing air through the sulphide (known as matte) getting metallic copper, sulphur dioxide, and ferrous oxide, which is slagged by addition of silica. This smelting may be done in either blast or reverberatory furnaces. The metal from the desulphurizing operation (converting) is then furnace refined if non-argentiferous, or by electrolysis if silver-bearing. Copper is also produced by direct reduction of oxide and carbonate or roasted sulphides to metal (black copper) and by wet processes, as at Rio Tinto, Wallaroo, Chuquicamata, etc.

A preliminary concentration of the copper minerals in an ore

by gravity or flotation is also much practised.

Fluorine.—A slightly greenish-yellow gas, occurring in nature chiefly in fluorspar. One of the most active of the elements. Combines with hydrogen even in the dark. It is the only element except those of the argon group which will not combine with oxygen. It attacks all metals except platinum and gold, and decomposes most organic compounds. It is used to etch on glass (as HF), as an electrolyte in lead refining (as H₂SiF₆), as a valuable flux (as CaF₂), and in the manufacture of aluminum (as Na₃AlF₆).

Gallium.—A rare metal which, although tough, may be cut with a knife. With aluminum it forms a liquid alloy which

will decompose water.

Gold.—Atomic weight, 197.2 (O = 16); trivalent; sp. gr., 19.29-19.37; the only yellow metal; most malleable and ductile of all metals; softer than silver, harder than tin; tenacity, about 14,000 lb. per sq. in. with 30.8 elongation. Melts at 1063°C., begins to volatilize at 1100°C. and volatilizes four times as fast at 1250°C. Electric conductivity 76.7 (Ag = 100). One oz. of gold leaf covers about 160 sq. ft. U. S. gold coin is 900 parts gold, 10 parts copper. Gold is recovered either by purely mechanical concentration (panning, etc.), by amalgamation, by dissolving it in chemical reagents (chlorination, cyanidation) or by recovering it in a fusion process with copper or lead. Has very small tendency to absorb gases when molten, but absorbs about 0.7 per cent. H, CO, and other electropositive gases when cold, if it is finely divided. It is dissolved by no one acid except nitrous, but is dissolved by any mixture (such as aqua regia) generating chlorine and bromine. Except in the thiosulphate, it does not play the part of base to oxy-acids.

Gold possesses the lowest solution tension of any metal. It may be precipitated from its solution by even the weakest reducing agents, such as H, P, As, Sb, C, by nearly all metals (except from cyanide solution, from which it can be separated only by zinc and metals more electropositive than zinc), by metallic sulphides, by protosalts of iron, tin, etc., by hypophosphites, sulphites, SO₂, the lower oxides of nitrogen, arsenic,

oxalic acid, etc.

Helium.—First discovered by spectroscopic observation of the sun. One of the rarest of the elements on the earth's surface. Found in some uranium minerals, is given off by the gases of certain springs, and is found in the air in the proportion of 0.0005 per cent. It is absolutely inactive. Atomic weight, 3.96.

Iodine.—Atomic weight, 126.92. Occurs at ordinary temperatures as beautiful violet to black crystals. It is largely used in the aniline color industry, in making iodoform and in potassium iodides in photography and medicine. The chief sources of iodine are the mother liquors of the Chilean nitrate industry and the ashes of sea weeds. It is readily precipitated from iodates thus:

 $2NalO_3 + 3Na_2SO_2 + 2NaHSO_3 = 5Na_2SO_4 + H_2O + I_2$

Iridium is insoluble in every acid, differs from platinum in not being soluble in aqua regia, although when the iridium is very finely divided it is attacked by this reagent. Fusion with acid potassium sulphate oxidizes it but does not dissolve it (distinction from ruthenium). It also oxidizes to the trioxide. lr₂O₃ when heated with fused sodium nitrate and hydroxide, or with hydroxide alone in the presence of air, but the residue is but slightly soluble in water. Iridium may be distinguished from platinum by suspending the precipitate produced with caustic alkalis in a solution of potassium nitrite and the solution saturated with SO₂ and boiled, renewing the water so long as SO₂ is given off, all of the iridium is converted to an insoluble brownish-green basic iridic sulphite. Iridic salts are reduced by alcohol in alkaline solutions to iridous compounds soluble in hydrochloric acid. For a method of decomposing osmiridium, see "osmium," p. 264.

Iron.—A white metal of atomic weight, 55.84. Forms two series of compounds, ferric (trivalent) and ferrous (bivalent) which pass from one form to the other by very gentle reduction

or oxidation.

Iron is the most magnetic of the metals. It alloys readily with most of the earth metals, only slightly with Pb and Cu. In the presence of Si, iron will dissolve more Cu than otherwise, that is cuprosilicon is dissolved more readily than is pure Cu. Fe

alloys readily with C, Si, P, S and O.

Iron Metallurgy.—Iron is produced by a reducing smelting after concentration or roasting or both. The slag, usually known as cinder, differs from that of the lead and copper metallurgists in being a calcium-aluminum silicate. The use of preheated blast, often previously dried, is also at variance with non-ferrous practice. The iron produced always contains Si, C, P, S, etc. Indeed most of the usefulness of iron depends on its carbon content; so a list is herewith appended of the carbides of iron and their modifications, with the names applied to them by the iron metallurgists.

Ferrite.—Chemically pure iron: α -iron, magnetic and free from C, passes at 780°C. into β -iron, which is non-magnetic and practically incapable of dissolving C. Above 880°C. β -iron passes into γ -iron which is non-magnetic and capable

of dissolving C or Fe₃C.

Cementite.—Iron carbide, Fe₃C.

Austenite and Martensite.—Solid solutions of Fe₈C in γ -iron.

Troosite.—Colloidal solution of Fe₈C in Fe.

Sorbite.—Mixtures of Fe, Fe₃C and solid solutions of Fe₃C in Fe.

Pearlite.—The eutectic between ferrite (Fe) and cementite (Fe₂C). It corresponds to 0.9 per cent. C, or (Fe₃C + 20Fe).

Temper Carbon.—Non-graphitic carbon which separates from white iron by keeping it for a long time at a temperature near 1000°C., during which time the finely divided cementite changes into a mixture of ferrite, pearlite and temper carbon.

Temper carbon is more readily oxidizable than graphite or carbide carbon.

Forgeable Iron.—The saturation point of Fe₂C in Fe is reached at 2 per cent. C (2 Fe₃C + 15Fe). Anything up to this point may be regarded as forgeable iron.

Steel Hardening.—This is explained by assuming a transformation of pearlite to martensite, and the maintenance of this

solid solution by quenching.

Malleablizing.—By exposing white iron for a long time to about 1000°C., the dissolved Fe₃C is converted into Fe and C. but the carbon is not present as graphite, but in an easily oxidized state. It is then oxidized by Fe₂O₃ or FeCO₃.

White iron is a supercooled solution and may be regarded as a metastable system between Fe₃C and Fe, in which the reaction Fe₃C = 3Fe + C has not been allowed to take place.

Gray iron is a stable system Fe—Fe₃C—C. It has had time, at the different temperatures and concentrations to reach a more or less complete state of equilibrium. During the cooling some of the Fe₈C has decomposed into Fe and C, the latter being found as graphite. See also Bessemer (p. 493), Thomas GILCHRIST (p. 496) and SIEMENS-MARTIN (p. 496).

Krypton.—Present in the proportion of 1:1,000,000 in air. Inert. Has a characteristic spectrum, noticed especially in the Aurora Borealis. Atomic weight, 45. Discovered by Ramsay in the last liquid from the evaporation of liquid air.

Lanthanum.—Greatly resembles cerium, which see. It occurs

chiefly in monazite sand.

Lead.—Atomic weight, 207.1; tetravalent; sp. gr., 11.35-11.37, when molten, 10.37-10.65; a dull gray metal, malleable but not ductile; tenacity the lowest of any common metal. Melts at about 326°C.; electric conductivity 10.7 with silver 100. Heaviest of all base metals. Fuses at 325°C.; boils at 1525°C. Has a great affinity for all the noble metals and is often used as a carrier in their extractions.

Lead is obtained by its ores by roast-reaction process $(2PbO + PbS = 3Pb + SO_2 \text{ or } PbSO_4 + 2PbS = 3Pb + 3SO_2);$ by the so-called precipitation process (PbS + Fe = Pb + FeS); or by reduction with carbon of oxide and carbonate ores or previously roasted sulphides. The argentiferous lead is refined by either the PARKES, PATTINSON or BETTS processes (q.v., pp. 493, 494, 495).

Lithium.—Atomic weight, 6.94; monovalent; sp. gr., 0.5936. A soft silver-white metal. Melts at 186°C.; vaporizes at about 1000°C. Below 200°C. may be melted in the air; above that, bursts into flame. Decomposes water at ordinary temperatures.

It is the lightest known metal.

Magnesium.—Atomic weight, 24.32; bivalent; sp. gr., 1.75. A white lustrous metal of fibrous crystalline structure. Malleable and ductile, not tough. Melts at 651°C.; boils at about 1120°C. Large pieces oxidize superficially. In powder burns readily. Combines readily with nitrogen at elevated temperatures. Is a good deoxidizer. Lightest of metals in common use. When powdered, it is highly combustible,

burning with a vivid light.

Manganese.—Atomic weight, 54.93; usually bivalent, may be heptavalent; sp. gr. given by various authorities at from 7.39 to 8.30. Silvery, lustrous, hard, brittle, smooth fracture. Melting point, 1260°C. Volatilizes considerably even at the melting point. Boils about 1900°C. Cannot be reduced by carbon to pure metal, as some Mn₃C is always formed, but can be produced in comparative purity by reduction of Mn₂O₃ by aluminum. Is used commercially mainly as ferromanganese, which is formed by direct reduction of manganese and iron ores.

Mercury.—Atomic weight, 200.6; bivalent; sp. gr., when fluid at 0°C., 13.59, solid at — 40°C., 14.19. Silver white with bluish tinge. Melts at — 39.38°C. Contracts on solidification, forming a white, very ductile, very malleable mass, which can be cut with a knife. Specific heat from — 78° to — 40°C. is 0.0247; of the fluid metal, 0 to 100°C., 0.0333. Electric conductivity at 22.8°C. is 1.63. Heat conductivity, 67.7 (Ag = 100). Boils at 360°C (Dulong and Petit). Amalgamates readily with gold, silver, zinc, tin, cadmium, lead and bismuth; with copper when finely divided; with arsenic, antimony and platinum with difficulty; with iron, nickel and cobalt not at all directly. Is obtained by smelting the ores and catching the flue dust, in which the mercury condenses.

Molybdenum.—Atomic weight, 95.3; quadrivalent; sp. gr., 8.62-9.01. A white, extremely lustrous, very hard metal. Acids scarcely affect it, except nitric, which converts it to molybdic oxide or acid. The sulphides readily form thio-salts with alkaline sulphides. Remains unchanged in air at ordinary temperatures, but oxidizes slowly when heated to redness. Used in high-speed steels, where it exercises about twice the influence that tungsten does. It cannot be produced pure by direct

reduction of the oxide by carbon.

The reduction test for molybdenum is as follows: A small quantity of molybdate or wulfenite, in a powdered state, together with a scrap of paper, should be placed in a test-tube with a few drops of water and an equal quantity of concentrated sulphuric acid. The tube and its contents should then be heated until the acid fumes begin to come over. After allowing the tube to cool, water should be added, a drop at a time. The addition of the first drops gives rise to a deep blue color, which disappears as more water is added.

Neodymium.—Greatly resembles cerium, which see.

Nickel.—Atomic weight, 58.58; sp. gr., cast, 8.35, rolled or hammered, 8.6 to 8.9; is very hard; can be rolled to sheets not over 0.0008 in. thick and drawn into a wire 0.0004 in diameter. According to Shakell the tenacity is 42.4 tons per sq. in. for annealed wrought nickel. It melts at 1452°C. when pure; the melting point is considerably lowered by carbon. Nickel is attracted by a magnet (Ni: Fe::1:1.54), but it loses this power at 340°C. Its electric conductivity is 12.9 (Ag = 100). The metallurgy of nickel somewhat resembles the fire metallurgy

of copper, in that the ores are smelted, following either wet concentration or roasting, or both, and the nickel-copper matte is bessemerized, but the converting process is not carried so far as in copper. In constitution nickel matte seems to vary, as the nickel content increases, from (Ni₂S and FeS) to (Ni₃S₂ and FeS) to pure Ni₃S₂ or even a solution of Ni in Ni₃S₂. Nickel speiss consists of Ni₅As₂, NiAs and probably Ni₈As₂. The partly bessemerized matter and speisses are then given the so-called "top and bottom smelting"—a reducing fusion with sodium sulphate. The product of this fusion consists of a layer of slag, a Cu-Fe-Na matte, and a Ni-Fe matte at the bottom. By repeated top and bottom smeltings a copper matte practically free from nickel and a nickel matte practically

free from copper are obtained.

The nickel matte is then worked up by one of numerous wet A part of the present Ni-Cu matte from the Canadian Copper Co.'s works is worked down into metal (the so-called monel metal) without separation of the nickel, copper The electrolytic baths are probably neutral sulphate containing considerable amounts of borate. An interesting method of nickel recovery from products in which the nickel occurs as oxide, oxide ores or wasted sulphides is the Mond process. A reducing roast is given the ores in retorts heated to 300°C. with gases containing H, whereby the nickel oxide is reduced to sponge Ni. The reduced nickel is then exposed to gas containing CO at 100°C. and 15 atmospheres pressure. Volatile nickel carbonyl is formed. This is stable at 50°C. at 2 atmospheres pressure; at 100° at 15 atmospheres; at 180° at 30 atmospheres; and at 250° at 100 atmospheres. The vapors of Ni(CO)₄ escaping from the vessels under pressure can be dissociated by simply lowering the pressure. The electrolyte formerly used by the Balbach works was said by ULKE to be a hot nickel sulphite, the current density to be 15 amp. per sq. ft. and a tank voltage of 1.7-1.8 volts.

Osmium.—The heaviest of all metals; sp. gr., 22.48; atomic weight, 190.9. Osmium is volatilized in, but not melted by the oxyhydrogen blowpipe. When strongly heated in contact with air the finely divided metal burns to osmic anhydride, OsO4 (usually known as osmic acid). This oxide is remarkable for its peculiar, exceedingly irritating and offensive odor. It is injurious to the eyes and is extremely poisonous. This oxide is soluble in water, giving a neutral solution, from which it is precipitated by nearly all metals, even silver, as a black precipitate. Fuming nitric acid or aqua regia also oxidizes osmium to OsO₄. When intensely ignited, osmium is rendered insoluble in acid, and must be fused with niter and distilled with HNO₃, when OsO₄ will distil over. All compounds of osmium yield the metal when ignited in hydrogen. Osmiridium may be attacked by mixing it with common salt or potassium chloride and exposing it in a glass or porcelain tube to a current of moist chlorine gas. Osmic acid is formed, which volatilizes below 212°C. and can be condensed and fixed by passing the

fume into an alkaline solution. Iridium remains behind in the

tube as a double chloride, 2KCl·IrCl₄.

Palladium is the most fusible of the so-called platinum metals. The metal oxidizes when heated in air. It absorbs hydrogen to a large extent. A solution of iodine produces a black stain on palladium, but has no effect on platinum. The best solvent for palladium is aqua regia. It is sparingly soluble in pure nitric acid, but dissolves more readily in fuming nitric acid, forming palladious nitrate, Pd(NO₃)₂. All palladium com-

pounds decompose on ignition.

Phosphorus.—Found in nature chiefly as the tri-basic calcium phosphate. To produce phosphorus the calcium phosphate is treated with sulphuric acid in lead-lined tanks. This converts the tricalcium into monocalcium phosphate. The clear solution is then drawn off and the precipitate thoroughly washed. The solution and washings are evaporated to 45°Bé, and about 25 per cent. of coke or charcoal added and the pasty mass dried in iron pans. The dry mixture is then distilled in cast-iron retorts and the fumes passed into a condenser containing water, under which the phosphorus collects. Phosphorus melts at 44°C, and distills at 269°C. It must be

kept under water.

Platinum.—Atomic weight, 195.2; tetravalent; sp. gr., cast, 21.5; a white metal of a grayish tinge; is very malleable and ductile; harder than copper, silver and gold; tenacity about 23,000 lb. per sq. in. (Deville and Debray); electric conductivity 13.4 at 0°C. (Ag = 100); melts at 1755°C., but is sensibly volatile at 1300°C. Is mainly recovered from alluvial deposits, but is also got in Wohlwill's process of electrolytic gold refining, where it remains in the solution. It is affected by fused alkaline hydroxides, phosphorus, cyanides, sulphides and halogens. Platinum is not acted upon either by pure hydrochloric, nitric or sulphuric acid. It dissolves in aqua regia and other mixtures, evolving chlorine, but less readily than gold, so that gold which has been fused to platinum can be dissolved by dilute aqua regia at moderate temperatures without injuring the platinum. When alloyed with silver, lead and some other metals it is dissolved (see tables on pp 328, 329).

Potassium.—Atomic weight, 39.1; monovalent; sp. gr., 0.865. A bluish-white metal, softer than sodium; fuses at 62.3° C., vaporizes about 700° C. The vapor is greenish. Like sodium in its reactions (q.v.). However, there is an explosive material left in the retorts when potassium carbonate is reduced by carbon, and the process is dangerous. It is found in greatest

abundance in the salt deposits of Stassfurt, Germany.

Præseodymium.—Greatly resembles neodymium, which see.

Occurs chiefly in monazite sands.

Rhodium is found in the insoluble residue resulting from the treatment of crude platinum with aqua regia. It is, when pure and in a compact state, not acted upon by even aqua regia, but when alloyed with lead, copper or bismuth in certain pro-

portions it dissolves in it. When alloyed with gold or silver it does not dissolve. It is oxidized by air at a red heat, or by fusion with potassium hydroxide and niter. It is converted by fusion with acid potassium sulphate into the soluble potassium rhodic sulphate K₆Rh₂(SO₄)₆. Mixed with sodium chloride and ignited in chlorine it forms the easily soluble 3NaCl-RhCl₂·H₂O. Rhodium is distinguished from the other platinum metals by its insolubility in aqua regia, its solubility in fused HKSO₄, and the formation of a brown precipitate on adding KOH and alcohol to rhodium-chloride solution.

Ruthenium is found in the insoluble residue resulting from the treatment of platinum ore with aqua regia. It is a grayishwhite metal, closely resembling iridium and very difficultly soluble. When heated in air it becomes covered with bluishblack ruthenic oxide, Ru₂O₃. When pure it is unacted on by acid, and is scarcely acted on by acid potassium sulphate. is attacked by fusion with potassium hydrate and niter, or potassium chlorate and is converted into K₂RuO₄, a darkgreen mass, soluble in water to an orange-colored fluid which stains the skin black. Ruthenium is rendered soluble by ignition with potassium chloride in a current of chlorine, being

converted to 2KCl·RuCl₄.

Selenium.—An element originally recovered from the dust chambers and mud of the lead chambers of sulphuric-acid plants. The classic process is to leach the mud with concentrated potassium cyanide, forming KCNSe, and then precipitating the Se by adding hydrochloric acid. My own process, by which much of the commercial selenium is now obtained, is to oxidize seleniferous flue dusts with HCl and NaClOs, then after all the free chlorine is gone, precipitate the metal with sulphur dioxide. The precipitate is then washed and dried. Selenium occurs in several amorphous modifications, some soluble in CS₂, some insoluble; in certain crystalline forms when precipitated from solution; in a vitreous form when melted and cooled quickly; and a so-called metallic form when melted and cooled slowly. This metallic modification has the remarkable property of altering its electric conductivity when illuminated. The vitreous modification passes over into the metallic when heated for some time above 180°F. considerable evolution of heat during the change.

Silver.—Atomic weight, 107.88; monovalent; sp. gr., cast 10.50, minted 10.57. Melts at 962°C., boils at 1850°C. Moissan). It is the whitest of metals, harder than gold, softer than copper, more malleable and ductile than any metal except gold, the best conductor of heat and electricity of known substances. (Some authorities state that gold is the best conductor of heat and copper of electricity. In any case the difference is slight.) It volatilizes at high temperatures, yielding a green vapor. In the molten state it has the property of absorbing twenty-two times its volume of oxygen, which is given out on cooling, causing the so-called spitting of silver. only with the pure metal. Small quantities of copper, bismuth and zinc entirely prevent it, as does also an inert cover. Arsenic antimony, bismuth and lead render silver brittle. It is recovered by amalgamation, by chemical processes (Augustin, Ziervogel, Kiss, Russell, Patera, Patio, Cyanide, etc.) and from the impure bullion from lead or copper smelting. From lead it is recovered by the Pattinson, Parks and Betts processes (q.v.) and from copper by electrolytic parting. In both these cases it contains gold, which is then recovered either by dissolving the silver by sulphuric or nitric acid, or by electrolytically refining the silver by the Moebius or Thum process. The auriferous silver bullion is known as doré. Silver does not oxidize in air, even if heated, but is easily attacked by sulphur and its compounds. It is attacked by nitric acid, and by hot sulphuric, scarcely at all by hydrochloric nor by the halogens and not at all by fused alkaline hydroxides.

Sodium.—Atomic weight, 23.00; monovalent, sp. gr., 0.974. A soft silvery-white metal, which may be kneaded at ordinary temperatures. Melts at 95.6°C.; vaporizes at about 900°C. Dissolves in anhydrous ammonia. Decomposes water at ordinary temperatures, and must be kept under oil. Burns in dry air to the peroxide, Na₂O₂. Practically all sodium compounds are soluble. Can be reduced from the carbonate by

carbon.

Strontium.—A soft white metal. Found chiefly in nature as carbonate and sulphate. Is used in the manufacture of

fireworks for red fire, and in the refining of sugar.

Tantalum.—Atomic weight, 181.5. A rare element usually occurring with columbium. Below 200°C. the metal is not attacked by air, oxygen or any acid except concentrated hydrofluoric. Not attacked by aqua regia, or by alkaline solutions, but is by fused alkalies. Can be used for electrolytic cathodes,

but not as anodes, as it oxidizes under anodic action.

Tellurium.—A metal much like selenium. Occurs usually as gold or silver telluride. About the only method of separating from selenium, if the two are mixed, is to make a fractional separation with SO₂, for selenium precipitates from concentrated hydrochloric-acid solutions with SO₂, while tellurium does not, or by taking a mixture of finely divided precipitates, leaching with concentrated cyanide solutions at ordinary temperatures, heating the solution, and filtering hot. The selenium is dissolved.

Tin.—Atomic weight, 119.0; quadrivalent; sp. gr., cast 7.287, rolled 7.30, tetragonal form (electrolytically deposited) 7.25, rhombic 6.55, ordinary commercial about 7.5, friable modification (due to tin pest) 5.8; melts at 232°C.; boils at 2100°C.; specific heat, 0.0562; coefficient of linear expansion, 0.00223; heat conductivity, 15.2 (Ag = 100). Most malleable at about 100°C., most brittle at about 200°C. Rolls to sheets not over ½000 inch thick. Tensile strength of very pure bars 2420 lb. per sq. in. (H. Louis), of hammered 2540 lb. per sq. in., commercial about 4600 lb. per sq. in., tin foil about 5980 lb. per sq. in. Breaks down at low temperatures to a gray granular

powder (tin pest); the change commences at 18°C., and is most rapid at -48°C. Boils at 1500° to 1600°C. if heated out of access of air. It is but little affected by air and moisture at ordinary temperatures. Electric conductivity, 14.4 (Ag = 100). Decreases in volume by 6.75 per cent. on solidification. Acted on by Cl, HCl, H2SO4 and HNO3, but is only oxidized by latter and does not form nitrates. Ores are usually concentrated, roasted if required and smelted in shaft or reverberatory furnaces, and refined by fire processes. Analyses of English tin show (H. Louis, "Metallurgy of Tin"): Sn, 98.64-99.76; Fe, tr-0.13; Pb, 0-0.20; Cu, tr-1.16. Tin from Pulo Brani showed, Sn, 99.76; Sb, 0.07; Pb, 0.02; Fe, 0.14; Cu, As, none. Is perceptibly volatile at 1200°C. Because of the high specific gravity of tin oxide it is ordinarily concentrated by mechanical means before smelting. The smelting of tin is difficult because it tends, when there is an excess of base in the slag, to enter it as an acid, forming stannites and stannates, while if there is an excess of silica tin enters the slag as a base.

Tungsten.—An almost white, very lustrous hard metal. Atomic weight, 184.0; sp. gr., 19.3-20.2. It begins to oxidize only at elevated temperatures in air. It can be reduced by carbon from the oxide. Ductile tungsten is practically insoluble in the common acids, it has the highest melting point of any metal (3267°C.); it is paramagnetic, and its wire can be drawn to smaller sizes than can the wire of any other metal. The chief commercially important forms are sodium tungstate, largely used for fireproofing and as a mordant, and tungsten as a constituent of high-speed steels. The recovery is entirely by chemical methods: (1) fusion with sodium carbonate; leaching out sodium tungstate with water; precipitation of WOs by acidifying with hydrochloric acid, followed by reduction with carbon. A little W₂C and WC is formed in this reduction and dissolved by the metal. Ferrotungsten can also be formed by direct reduction of wolframite or scheelite with iron compounds and powdered quartz or glass. The carbonfree metal can also be produced by the aluminum-reduction process.

A general test for all tungsten ores is carried out as follows: Strong hydrochloric acid is added to the ore, which is first pulverized to as fine a powder as possible, and part of the tungsten will pass into the solution. Metallic zinc should then be added and the mixture boiled. A fine azure blue denotes the presence of tungsten.

When any ore containing tungsten is fused with sodic carbonate, leached out with hot water and filtered, the tungsten passes into the filtrate. If hydrochloric acid is added the tungsten is precipitated. This precipitate is insoluble in all acids, dissolves readily in ammonia, and is of a fine yellow color. A little of this yellow powder, if added to a bead of salt of phosphorus and treated in a reducing flame, using a blow lamp, gives the fine blue bead characteristic of tungsten.

Uranium.—A white lustrous, very hard metal, oxidizing in

air only at high temperatures, but igniting in pure oxygen at 170°. Fluorine attacks it at ordinary temperatures, chlorine at 180°, bromine at 210° and iodine at 260°C. It combines with sulphur at about 1000°C. to form a black sulphide and with

nitrogen at about 1000°C. to produce a yellow nitride.

Vanadium.—Atomic weight, 51.0; sp. gr., 5.50; melts at 1720°. According to Borchers the purest metal yet obtained was a gray lustrous powder which ignites readily in the Bunsen flame. It dissolves with great difficulty in hydrochloric or dilute sulphuric acid, but more readily in strong sulphuric acid, in hydrofluoric acid or in nitric. With fused alkali-metal hydroxides it forms vanadates. At elevated temperatures it combines readily with the halogens, sulphur, or even with nitrogen.

Xenon.—Occurs in the atmosphere in the proportion of

1:20,000. Heaviest of the rare gases.

Zinc.—Atomic weight, 65.37; always bivalent; sp. gr., cast, from 6.861 to 7.149; when rolled, 7.2 to 7.3; when fluid, 6.48 to 6.55. Boils at about 920°C. Melts at 415°C. Specific heat at 0° to 100°C., 0.09555 (REGNAULT); probably 0.1015 from 100° to 300°C. It burns in air at about 505°C. Zinc is brittle at ordinary temperatures, especially if impure, but between 100°C. and 150°C. it becomes malleable and ductile, and may be rolled into sheets and drawn into wire, and retains these properties after cooling. At 205°C. it again becomes so brittle that it may be powdered in a mortar. When cast at a temperature near its melting point it is more malleable than when cast at a higher temperature. In malleability zinc ranks between lead and iron; inductility between copper and tin. In hardness it stands between copper and tin; more exactly between silver and platinum, being 2.5 on Moh's scale, 6 on Turner's sclerometer, and 1077 on Bottone's scale, on which the diamond is The thermal conductivity is given from 19 (WIEDEMANN) to 64.1 (CALVERT and JOHNSON), silver being 100. Its electrical conductivity is 16.92, mercury at 0°C. being unity. On the basis of silver = 100, Becquerel gives its conductivity at 24.06, and Weiller at 29.90. According to Roberts-Austen the coefficient of linear expansion is 0.0000291; CALVERT and Johnson give it at 0.00002193 for hammered zinc. The tensile strength of zinc varies from 2700 lb. per sq. in. for cast metal to 17,700 for an annealed rod. Zinc dissolves readily in both acid and alkaline solutions with evolution of hydrogen. A moderate tenor in lead makes zinc malleable and ductile; over 1.5 per cent. Pb is certainly detrimental. Iron up to 0.2 per cent. does not greatly affect the properties of zinc, above that it makes it less fluid, less malleable, less strong, harder and more brittle. Cadmium seems to have no injurious influence except when the spelter or ore is to be used for making zinc oxide. Copper makes zinc harder and more brittle, even if only 0.5 per cent. be present. Tin also makes it harder and more Other impurities are of minor importance, but silver, thallium, indium, magnesium, aluminum, antimony, arsenic, sulphur, carbon, chlorine and oxygen occur. The metal

is produced by smelting the ores in retorts with carbon as a reducing agent, and extraneous fuel to heat them. A fusible slag is not wanted. Sulphide ores must be roasted clean before distillation. The loss of zinc in the smelting process, due to retort absorption, escape through the pores of the retorts, escape of uncondensed zinc through the adapters, through zinc left in the retorts, etc., is very seldom below 10 per cent. and may amount to 25 per cent.

Zirconium.—Atomic weight, 90.6; sp. gr., 6.4; melts about 2350°C., occurs as the natural oxide and as the silicate (zircon). It was used as the incandescing material in the first gas mantles.

DETECTION OF THE METALS

Aluminum.—Is precipitated as white gelatinous hydroxide by ammonia. When the oxide is strongly heated on charcoal with cobalt nitrate, a bright-blue mass is obtained. With soda before the blowpipe it swells and forms an infusible compound.

Antimony.—When a small quantity of an antimony compound is heated in the upper reduction zone of a Bunsen burner on a thread of asbestos, the flame is given a bluish tinge and when a small porcelain basin filled with cold water is held above it, a brownish-black deposit of metallic antimony is deposited upon the basin, and this is but slightly attacked by cold nitric acid and is insoluble in sodium hypochlorite. Arsenic gives a similar reaction, but arsenic gives a garlic-like odor during the reduction, and the metallic film is readily soluble in the hypochlorite. Antimony compounds may be obtained in solution by treating with HCl or by fusing first with potassium carbonate and potassium nitrate. Hydrogen sulphide produces in acid solution a very characteristic orange-red-colored precipitate of antimony trisulphide. Blowpipe tests-on coal, reducing flame, volatile white coat, bluish in thin layers, continues to form after cessation of blast. With bismuth flux on plaster, orange-red coat, made orange by (NH₄)₂S; on coal, faint yellow or red coat. In open tube, dense, white, non-volatile amorphous sublimate. The sulphide, too rapidly heated, will yield spots of red. In closed tube the oxide will yield a white fusible sublimate of needle crystals; the sulphide, a black sublimate, red when cold.

Arsenic.—Mix with sodium carbonate and heat on charcoal with the blowpipe. All arsenic compounds give a garlic odor. Add to concentrated hydrochloric acid a few drops of an arsenite solution and half a cubic centimeter of saturated solution of stannous chloride in hydrochloric acid, warm, and the solution turns brown, then black. Blowpipe—on smoked plaster gives a white coat of octahedral crystals. The action on coal has already been spoken of. With bismuth flux on plaster Sb gives a reddish-orange coat, made yellow by (NH₄)₂S; on coal a faint yellow coat. In open tube it gives a white sublimate of octahedral crystals. Too high heat may form

brown suboxide or red or yellow sulphide. In closed tube may give white oxide, yellow or red sulphide, or black mirror of metal. Flame—azure blue.

Barium.—The Bunsen flame is colored a yellowish-green tint when any volatile barium compound is brought into it. Soluble barium salts are distinguished from those of strontium and calcium inasmuch as they are immediately precipitated by a solution of calcium sulphate. Blowpipe—on coal, with soda, fuses and sinks into the coal. The yellow-green flame can be

improved by moistening with HCl.

Bismuth.—On charcoal with soda, bismuth gives a very characteristic orange-yellow sublimate. Brittle globules of the metal are also reduced on the charcoal when treated with soda. Hydrogen sulphide precipitates from solutions of bismuth salts a blackish-brown sulphide (Bi₂S₃) insoluble in ammonium sulphide and easily soluble in nitric acid. Ammonia throws down a white basic salt insoluble in excess. Blowpipe—with bismuth flux (sulphur, 2 parts; potass. iodide, 1 part; potass. bisulphate, 1 part) on plaster, bright scarlet coat surrounded by chocolate brown with sometimes a reddish border. The brown may be made red with ammonia. With bismuth flux, on coal, gives a bright-red coat with sometimes an inner fringe of yellow.

Cadmium.—Cadmium is precipitated as a yellow sulphide by hydrogen sulphide. The sulphide is insoluble in ammonium sulphide and in the caustic alkalies. On charcoal with soda, compounds of cadmium give a characteristic sublimate of the

reddish-brown oxide.

To test for cadmium in a sulphide, roast it to oxide, and reduce some of the oxide in the upper reducing flame of the Bunsen burner, at the same time holding a glazed porcelain dish which contains water just above the flame to receive a brown coating. To the brown coating add a drop of AgNO₃ solution; if Cd is present, black metallic silver will be deposited. Blowpipe—on coal, reducing flame, greenish yellow in thin layers. Beyond the coat, at first part of operation, the coat shows a variegated tarnish. On smoked plaster with bismuth flux Cd gives a white coat made orange by (NH₄)₂S. With borax or sodium phosphate, oxidizing flame, clear yellow hot, colorless cold, can be flamed milk white. The yellow bead touched to Na₂S₂O₃ becomes yellow.

Cæsium.—H₂PtCl₆ produces a bright-yellow crystalline precipitate, a brighter color than the potassium salt thus produced, and is much more soluble than the potassium salt.

The flame test is reddish violet, similar to potassium.

Calcium.—Calcium compounds moistened with hydrochloric acid and placed on a platinum wire in the hottest part of a

Bunsen flame impart a red color to the flame.

Calcium may be precipitated from solution as oxalate by first making the solution ammoniacal and then adding ammonium oxalate or oxalic acid. Blowpipe—on coal with soda, insoluble and not absorbed by the coal. Flame—yellow red,

improved by moistening with HCl. With borax or sodium

phosphate, clear and colorless; can be flamed opaque.

Cerium.—Fuse with sodium carbonate. Treat with dilute hydrochloric acid, evaporate to dryness and bake. Take up with dilute hydrochloric acid, filter. Add ammonia to the filtrate, filter. Dissolve the precipitate in hydrochloric acid, add ammonia and oxalic acid, filter. Dissolve the precipitate in concentrated hydrochloric acid, nearly neutralize with ammonia; add 1 cc. of hydrogen peroxide and then ammonia, drop by drop, until just alkaline. When just neutral, white thorium peroxide is precipitated; when ammoniacal, the orange

cerium peroxide is precipitated.

Chromium.—Chromium oxide is detected in its insoluble compounds by its characteristic green color. It forms an emerald-green head with borax or microcosmic salt. Caustic potash or soda gives a green precipitate in solutions of chromic salts. This dissolves in an excess of alkali in the cold, but is precipitated on boiling the solution. The detection of chromic acid is rendered easy by the bright-yellow color of its salts. The yellow color of the normal chromates becomes red on the addition of an acid, and again yellow when made alkaline. Blowpipe—with borax or sodium phosphate, oxidizing flame, reddish when hot, fine yellow when cold. Reducing flame, in borax, green hot and cold. In sodium phosphate, red when hot, green when cold. With soda—oxidizing flame, dark yellow when hot, opaque and light yellow cold. Reducing flame, opaque and yellowish green cold. Manganese interferes, giving a bright yellowish green with soda bead in the oxidizing flame.

Cobalt.—Ammonium sulphide produces a black precipitate (CoS) insoluble in acetic acid and in dilute hydrochloric acid. Ammonium sulphocyanate produces a beautiful blue color, Co(CNS)₂. With a borax bead cobalt gives the characteristic cobalt-blue color. Blowpipe—on coal, reducing flame, the oxide becomes magnetic metal. The solution in HCl will be rose-red, but on evaporation will be blue. With borax or

sodium phosphate, pure blue in either flame.

Columbium.—Fuse with potassium bisulphate. Pulverize the fusion and treat it with hot water; then treat it with dilute hydrochloric acid. Digest the residue with ammonium sulphide to remove W, Sn, etc. Wash and treat again with dilute hydrochloric acid. The residue should be colorless and contain only silica and the oxides of columbium and tantalum. This residue in a bead of microcosmic salt is colorless if no columbium is present or if heated in the oxidizing flame; but if heated in the reducing flame, columbium imparts a violet color to the bead, or blue if saturated with oxide. Adding ferrous sulphate turns the bead blood red.

If, when the mixed oxides are boiled in dilute sulphuric acid with metallic zinc, the white precipitate turns intensely blue and remains so on dilution, columbium is present; if it turns bluish gray and colorless on dilution, tantalum is predominant.

Copper.—Copper can easily be detected by the reduction

to the red metallic bead on charcoal before the blowpipe. Copper compounds moistened with HCl color the non-luminous flame green. An excess of ammonia added to a nitric acid solution of copper produces an azure-blue color. With borax or sodium phosphate, oxidizing flame, green when hot, blue or green blue cold. (By repeated oxidation and reduction, the borax bead becomes ruby red.) Reducing flame, green or colorless hot, opaque and brownish red cold.

Erbium.—Erbium oxide heated on a platinum wire colors

the flame distinctly green.

Gallium.—If a neutral solution of gallium chloride be warmed with zinc, gallium oxide or basic salt separates but not the metal.

Germanium.—Fuse with sulphur and sodium carbonate. Treat with hot water, filter, add a few drops of hydrochloric acid to the filtrate to precipitate white germanium sulphide. Filter and heat the residue in a current of hydrogen to reduce it to gray-black crystalline germanous sulphide. Dissolve the crystals in hydrochloric acid and pass hydrogen sulphide into the solution to precipitate reddish-brown germanous sulphide.

Glucinum.—Ammonium carbonate produces a white precipitate, GlCO₃, soluble in an excess of the reagent; by boiling

the solution it is precipitated as a basic carbonate.

Gold.—Gold may be reduced from its ores on charcoal to a yellow malleable bead which is soluble in aqua regia; if the solution be dropped on filter paper and one drop of stannous chloride added, a purple-red color is produced.

Indium.—Heated on charcoal before the blowpipe it colors the flame blue, and gives an incrustation of the oxide. It slowly dissolves in hydrochloric and dilute sulphuric acids,

but readily in nitric acid.

Iridium.—Ammonium chloride produces in a tolerably concentrated solution of iridium a dark-red crystalline precipitate. Iridium is distinguished from platinum by the formation of a colorless solution of potassium chloriridiate when caustic potash is added to the chloride of the metal, and on exposure to the air this colorless solution first becomes red colored and afterward blue.

Hydrogen sulphide precipitates brown iridium sulphide,

which is soluble in ammonium sulphide.

Iron.—Ferrous salts with potassium ferricyanide produce a dark-blue precipitate. Ferric salts with ammonia or the fixed alkalies produce a brown precipitate. Ferric salts with potassium or ammonium sulphocyanate produce a blood-red-colored precipitate. Ferrous salts with a bead of microcosmic salt or borax are colored dark green. This color readily changes to yellow or reddish brown by oxidation. Blowpipe—on coal, with reducing flame, many compounds become magnetic. Soda assists this reaction. With borax, oxidizing flame, yellow to red hot, colorless to yellow cold. With reducing flame, bottle green. With tin on coal, violet-green. With

sodium phosphate, oxidizing flame, yellow to red hot, greenish when cooling, colorless to yellow cold. Reducing flame, red

both hot and cold, greenish when cooling.

Lead.—Black precipitatate formed with hydrogen sulphide, chrome yellow with chromates. In nitric acid solution dilute sulphuric acid gives a white precipitate of lead sulphate. Blowpipe —on coal, lead is reduced in either flame to malleable metal, and yields near the assay a dark lemon-yellow coat, sulphur yellow cold, and bluish white at border. The phosphate yields no coat without the aid of a flux. With bismuth flux on plaster chrome-yellow coat, blackened by (NH₄)₂S. On coal, volatile yellow coat, darker hot. Flame, azure blue. With borax or sodium phosphate, oxidizing flame, yellow hot, colorless cold. Flames opaque yellow. In reducing flame, borax bead becomes clear; S. Ph. bead, cloudy.

Lithium.—In the Bunsen flame a fine carmine-red color is produced, visible if sodium is present by viewing the flame through cobalt glass. If silicon is present, make into a paste with boracic-acid flux and water and fuse in the blue flame.

Just after the flux fuses the red flame will appear.

Magnesium.—To a solution of magnesium add ammonium chloride, ammonia and sodium phosphate; a white precipitate (MgNH₄PO₄) forms. The action is hastened by rubbing the sides of the beaker with a glass rod. Blowpipe—on coal, with soda, Mg is insoluble and not absorbed by the coal. With borax or sodium phosphate, clear and colorless; can be flamed opaque white. With cobalt solution, strongly heated, becomes a pale flesh color. (With silicates this action is of use only in absence of coloring oxides. The phosphate, arsenate and borate become violet colored.)

Manganese.—Ammonium sulphide produces a flesh-colored precipitate. A solution containing traces of manganese boiled in concentrated nitric acid with lead peroxide or sodium bismuthate and allowed to settle gives a violet-red-colored solution (HMnO₄). The borax bead with manganese in the oxidizing flames gives an amethyst-colored bead (with much, black or opaque) and this in the reducing flame becomes colorless or with black spots. With soda, oxidizing flame, bluish green and opaque when cold. Nitrate assists the reaction. If silicon is present, dissolve in borax, then make soda

fusion. Mercury.—Stannous chloride heated with a solution of mercury precipitates gray metallic Hg. Mercury compounds mixed with sodium carbonate and heated in a closed tube produce a gray mirror of metallic Hg. With bismuth flux, on plaster, Hg gives a volatile yellow and scarlet coat. If too strongly heated the coat is black and yellow. On coal Hg gives a coat faint yellow at a distance. In matrass gives mirror-like sublimate, which may be collected in globules. (Gold leaf is

whitened by the least trace of mercury vapor.)

Molybdenum.—To a strong nitric acid solution of molybdenum add nearly enough ammonia to neutralize the acid and

then add a few drops of sodium phosphate solution. A bright-yellow, crystalline precipitate forms when the solution is warmed. A hydrochloric or sulphuric acid solution of molybdenum, to which zinc or stannous chloride is added, turns first blue, then green, and finally brown. On coal, with oxidizing flame Mo gives a coat, yellowish when hot, white when cold, crystalline near assay; in reducing flame the coat is turned in part deep blue, in part copper red. Its Bunsen-burner flame is yellowish green. With borax, oxidizing flame, yellow when hot, colorless when cold. Reducing flame, emerald green.

Neodymium.—The didymium salts are violet and are identi-

fied by a characteristic absorption spectrum.

Nickel.—Potassium cyanide produces a bright-green precipitate, Ni(CN)₂. When nickel compounds are heated with reducing agents before the blowpipe, an infusible magnetic powder is produced. If this powder is dissolved in a drop or two of dilute nitric acid and evaporated to complete dryness, a characteristic green stain is obtained which becomes yellow on further heating. Nickel compounds color the borax bead brownish yellow in the oxidizing flame, the bead becoming gray and opaque in the reducing flame, owing to the separation of metallic nickel. Nickel is precipitated in alkaline solution by ammonium sulphide, which dissolves in an excess of ammonium sulphide forming a dark-colored solution.

Osmium.—It is dissolved in fuming nitric acid, or by fusing with sodium hydroxide and potassium nitrate and then treating with nitric acid and distilling. Osmic oxide (OsO₄), which sublimes at a moderately low temperature, passes over and condenses as a colorless crystalline mass. The osmic oxide has

an odor similar to chlorine and is poisonous.

Palladium.—Dissolves in nitric acid or aqua regia. Potassium iodide added produces a black precipitate, palladous iodide (PdI₂), soluble in an excess of the reagent but not soluble in water, alcohol, or ether. Mercuric cyanide, Hg(CN)₂, produces a yellowish-white gelatinous precipitate, Pd(CN)₂, which, on ignition, leaves the spongy metal. See also special articles on palladium determination on p. 264.

Platinum.—When heated with sodium carbonate on charcoal, gray spongy metal is reduced. This, rubbed on a mortar with a pestle, gives a metallic luster and is insoluble in any single acid. See also special articles on platinum determination on p. 264.

Potassium.—A solution of H₂PtCl₆ added to concentrated solutions of potassium gives a yellow precipitate K₂PtCl₆. In the Bunsen flame potassium gives a violet color, visible if sodium also is present if viewed through cobalt glass.

Praseodymium.—See Neodymium.

Radium.—To the Bunsen flame a radium salt imparts an intense carmine-red color. Radium rays discharge a charged electroscope and may be used for making photographs on ordinary X-ray plates.

Rhodium.—Before the blowpipe on charcoal with sodium carbonate the salts of rhodium are reduced to the metal, which

is insoluble in aqua regia, but may be dissolved by fusing it with potassium pyrosulphate and then treating the fusion with water. By adding to this solution potassium hydroxide and a little alcohol the brown rhodium hydroxide is formed.

Rubidium.—A solution of H₂PtCl₆ produces a white crystalline precipitate, Rb₂PtC₆, which is less soluble than the corresponding potassium salt and more soluble than the cæsium salt. The flame test gives a color similar to the cæsium test.

Ruthenium.—Ruthenium is practically insoluble in all acids and in aqua regia. Fuse it with potassium hydroxide and potassium nitrate. The resulting K₂RuO₄ heated with NaCl in a current of chlorine yields soluble K₂RuCl₆. The greenish-black fusion treated with water yields an orange-yellow solution, which stains the skin black.

Scandium.—A hydrochloric acid solution of scandium treated with solid sodium silicofluoride and boiled 30 min. gives a precipitate containing scandium free from the rare earth metals.

Silver.—When fused with sodium carbonate on charcoal before the blowpipe, a bright metallic silver bead is produced, which may be dissolved in nitric acid and precipitated from the solution by hydrochloric acid as a curdy precipitate of silver chloride, or, if only a trace of silver is present, as a mere opalescence.

Sodium.—To a neutral or weakly alkaline solution add potassium pyroantimonate, $K_2H_2Sb_2O_3$, and a heavy white crystalline precipitate, $Na_2H_2Sb_2O_3$, is quickly formed by rubbing the sides of the beaker with a glass rod. Solutions of sodium on a platinum wire in a Bunsen flame give a yellow

color.

Strontium.—Solutions on a platinum wire color the Bunsen flame carmine red, improved by moistening with HCl. Strontium sulphate is less soluble than calcium sulphate, but more soluble than barium sulphate. If barium is present the flame turns brownish yellow. The lithium flame is unaffected by addition of barium chloride.

Sulphur.—Fuse on coal with soda and a little borax in the reducing flame and place melt on a bright silver coin. Moisten, crush, and let stand. In presence of sulphur the coin will

turn brown or black.

Thallium.—Dissolve in dilute acid, add H₂S, filter. Add to the filtrate ammonium sulphide and filter. If thallium is present in the precipitate it will color the Bunsen flame emerald

green.

Thorium.—Fuse in a platinum crucible with sodium carbonate. Cool, dissolve in water and hydrochloric acid. Evaporate to dryness and bake. Take up with dilute hydrochloric acid, filter. Add ammonia to the filtrate, filter. Dissolve the precipitate in hydrochloric acid; reprecipitate with oxalic acid, filter, ignite the residue. Dissolve in hydrochloric acid. Evaporate to dryness. Take up with water. Add an excess of sodium thiosulphate and boil to precipitate.

Tin.—Mercuric chloride added to a solution of a stannous

salt precipitates white mercurous chloride. A trace of stannous chloride in solution added to a solution of gold chloride precipitates finely divided gold, brown by transmitted light and bluish green by reflected light. Metallic zinc precipitates tin from solution as a spongy mass, which adheres to the zinc. Heat the ore on charcoal with sodium carbonate or potassium cyanide; a metallic bead is produced which is coated with white oxide when the flame is removed. Cassiterite in lumps in a test-tube with metallic zinc and dilute sulphuric acid is soon coated with metallic tin.

Titanium.—Titanium sulphate with hydrogen peroxide in a slightly acid solution produces an orange-red color, or a clear yellow with small amounts of titanium. Vanadic acid with hydrogen peroxide produces a similar effect. Tin or zinc in hydrochloric acid solutions of titanium produces a violet color due to Ti₂Cl₂.

Tungsten.—Treat with hydrochloric and nitric acids (4:1) and take to dryness, wash by decantation, add dilute hydrochloric acid and metallic zinc, aluminum, or tin and shake; a fine blue coloration or precipitate is produced, W₂O₅; the color disappears when diluted with water. Fuse in platinum with potassium bisulphate, digest with a solution of ammonium carbonate, filter, add to the filtrate a few drops of SnCl₂ solution, acidify with hydrochloric acid, warm gently; a fine blue color is produced. The microcosmic salt bead made in the reducing flame is clear blue; if iron is also present, the bead will be red brown. In the oxidizing flame the bead is colorless.

Uranium.—Potassium ferrocyanide produces a brown precipitate, in dilute solution a brownish-red coloration. The borax (or microcosmic salt) bead is yellow in the oxidizing

flame and green in the reducing flame.

Vanadium.—Vanadium compounds can be dissolved by a treatment with acids or alkalies. The hydrochloric acid solution assumes a bright blue color on addition of zinc. solution of hydrovanadic sulphate cannot be distinguished in color from one of copper sulphate when sufficiently diluted with water, but, of course, does not become colorless in the presence of metallic iron. Solutions of certain vanadates also closely resemble solutions of the chromates. For instance, a solution of the tetravanadate of potassium, K₂V₄O₁₁, does not differ in appearance from one of potassium dichromate. They may, however, be distinguished from one another, since the vanadate solution becomes blue and the chromate assumes a green color on deoxidation. When a solution of vanadic acid or an acid solution of an alkali vanadate is shaken up with ether containing hydrogen peroxide, the aqueous solution assumes a red color like that of ferric acetate. This reaction serves to detect one part of vanadic acid in 4000 parts of the liquid. Chromic acid does not interfere with the reaction.

Yttrium.—Extract the yttrium in the manner described under Cerium and separate it from the other rare earths in a solution of their sulphates by adding a saturated solution of

potassium sulphate. Yttrium sulphate is soluble; the others are not.

Zinc.—Ammonium sulphide precipitates ZnS. Potassium ferrocyanide produces a white precipitate, Zn₂Fe(CN₆). Before the blowpipe on charcoal with sodium carbonate, a coating of oxide is produced which is yellow while hot and white when cold. With cobalt nitrate on charcoal an infusible green mass

is produced.

Zirconium.—Treat with dilute sulphuric acid (2:1), filter, add ammonia to the cold filtrate, filter; wash, dissolve the precipitate in hydrochloric acid, evaporate to dryness. Take up with a little water and add to the cold saturated solution hydrochloric acid, drop by drop; if zirconium is present, the oxychloride will be precipitated. Heat to dissolve the precipitate. Cool and after some time fine silky needles of ZrOCl₂ + 8H₂O will precipitate.

DETERMINATION OF PLATINUM, PALLADIUM AND GOLD¹

Scorify the lead buttons from two or more 1/2-a.t. crucible fusions together, adding at least six times as much silver as the combined weight of the Pt, Pd and Au present, and cupel hot. In rich materials such as slimes or concentrates, two 1/2-a.t. fusions suffice, but low-grade ores may require 10 or more 1/2-a.t. fusions combined for each determination.

Part the silver beads with HNO₃ (1:6), followed by stronger parting acid (1:1) and wash with water as usual. All Pd goes into solution, together with considerable Pt. The residue consists of Au plus some Pt. Dissolve residue in strong aqua regia and reserve the solution (solution A). Precipitate the silver in the nitric-acid solution—containing Ag, Pd and some Pt—with HCl. Practically all the Pt will remain in solution; but the precipitated AgCl is pink in color and contains considerable Pd. Filter off the AgCl, scorify and cupel it and part again with HNO₃ (1:6); all should dissolve. Reprecipitate the Ag with HCl. The liquid now contains most of the remaining Pd, but some is co-precipitated with AgCl. the AgCl and add the filtrate to the first filtrate from AgCl. Again scorify and cupel the silver chloride, dissolving the silver in nitric acid as before and reprecipitating the silver as chloride. In most cases the filtrate from this silver chloride contains all the remaining Pd. If, however, the AgCl is distinctly pink, another separation must be made.

Unite all filtrates from AgCl precipitations and evaporate to small bulk, adding the aqua-regia solution of the Au and Pt (solution A). The liquid now contains all the Au, Pt and Pd present in the original ore, together with traces of Ag due to solubility in AgCl in excess of HCl, and also traces of Pb gathered from the lead retained in the silver buttons from the several recupalistics.

several recupellations.

¹ From an article by A. M. Smoot, Eng. and Min. Journ., Apr. 17, 1915.

Evaporate the liquid to dryness on the steam bath; take up with dilute HCl (1:3) and evaporate again to dryness; take up with five drops of HCl and 40 cc. H₂O. Pay no attention to any insoluble residue of AgCl or PbCl₂.¹ Precipitate gold by adding, say, 3 grams of oxalic acid to the solution and boiling it. Let stand over night and filter off the Au. If Pt and Pd are high, it is necessary to redissolve the Au in aqua regia, evaporating with HCl to dryness and repeating the oxalic-acid precipitation, uniting the filtrate with that from the first gold precipitation. Burn the filter containing the gold and scorify it with six times its weight of silver and a little test lead; cupel,

part and weigh the gold as usual.

To the oxalic-acid filtrates from Au add 5 cc. of HCl and make volume up to 150 cc.; heat to boiling and precipitate Pt and Pd with a rapid current of H2S in hot solution, passing the current of gas for some time and keeping the solution hot during precipitation. Filter and wash the Pt and Pd sulphides with H₂S water containing a little HCl. Wash the precipitate from the filter with a fine water jet into an original beaker; spread the filter paper (which will contain a small amount of precipitate impossible to wash off) with the precipitate side down over the lower side of a watch-glass cover. Add aqua regia to the precipitate in the beaker and place the cover on the beaker; warm gently to dissolve the Pt and Pd sulphides. The fumes arising from the acid dissolve the traces of Pt and Pd adhering to the filter paper. When solution is complete and the filter paper is white, remove the watch-glass cover and wash the paper with hot dilute HCl thrown against it in a fine stream.

Evaporate the aqua-regia solution to dryness, take up the residue with HCl and evaporate again to dryness to remove all HNO₃. Take up the residue with two or three drops of HCl and about 2 cc. of H₂O. The solution is usually perfectly clear, but it may be slightly cloudy owing to the presence of a little AgCl in it. No attention need be paid to this, however. Add 5 to 10 cc. of a saturated solution of NH₄Cl, stir well and allow to stand over night. Platinum is precipitated as ammoniumplatinum chloride—(NH₄)₂PtCl₆. Filter and wash the precipitate with 20 per cent. NH4Cl solution. All Pd passes into the filtrate which is reserved (solution B). Dissolve the Pt precipitate in boiling hot 5 per cent. H₂SO₄; heat the liquid to actual boiling and precipitate with H2S as before, filtering and washing with H2S water. Burn the filter and precipitate at a low temperature in a scorifier; add six times as much Ag as Pt, scorifying with lead, cupel and part the silver bead containing the platinum with H2SO4; decant off the silver solution and

¹ In materials rich in palladium the small amount of AgCl + PbCl² may be distinctly pink in color and retain weighable quantities of Pd. If this is the case, the Pd may be recovered in the solution from the nitric acid parting of the gold. To do this, precipitate the silver in this liquid by adding HCl, filter off the silver chloride and evaporate the filtrate to dryness. Take up with a drop of HCl and a little water, let stand over night and filter through a very small filter. This liquid may be added to solution B before precipitating palladium with glyoxime.

wash once with strong H₂SO₄, followed by 50 per cent. H₂SO₄ until practically all silver is washed away; finally wash with water, anneal and weigh. A minute quantity of Ag is retained with the platinum, but it can usually be neglected. In very important work where the amount of platinum is large dissolve in aqua regia, evaporate the solution to dryness, take up with a drop of HCl, dilute largely with water and let the AgCl settle over night; filter on a small paper, cupel it with a little sheet lead and deduct the weight from the weight of platinum. This refinement need not be considered in materials running less than 15 or 20 oz. to the ton.

It may seem an unnecessary step to precipitate the platinum as sulphide, scorify it with silver and part it as described in the foregoing. General practice has been to ignite the ammonium-platinum-chloride precipitate and weigh the metallic residue. When this is done, however, there is danger of losing considerable platinum, which is carried away mechanically during the decomposition of the compound; furthermore, it is extremely difficult (if not impossible) to collect the finely divided residue for weighing, and the precipitate invariably contains lead and silver. Precipitation as sulphide, scorification and cupellation with excess silver and parting with sulphuric acid overcome the difficulties inherent in handling the ammonium precipitate.

The palladium is all contained in the filtrate and washings from the platinum-ammonium-chloride precipitates (solution B). Add to this solution at least seven times as much dimethylglyoxime as there is Pd present (in any case, at least 0.1 gram glyoxime). The precipitant should be dissolved in a mixture of two-thirds strong HCl and one-third water. Dilute the liquid to 250-300 cc., heat on a steam bath for half an hour and let stand over night. Pd is precipitated as a voluminous, yellow, easily filtered glyoxime compound (C₈H₁₄N₄O₄)₃Pd, containing, when dried at 110°C., 31.686 per cent. of Pd. Filter the Pd precipitate on a weighed Gooch crucible and wash it first with dilute HCl, half and half, then with warm water and finally with alcohol; dry it at 110° to 115°C. and weigh. The disadvantage of weighing palladium on a Gooch crucible is overcome—at least to some extent—by the fact that the Pd compound contains a relatively small amount of Pd—less than one-third of its weight. This compound may also be weighed on carefully counterpoised papers; but it is better to use Gooch crucibles, if they are available, because of the relatively strong acid which is required for washing. The object in using half-and-half hydrochloric acid as a wash liquid is to dissolve out any excess of the glyoxime precipitant. This is easily soluble in moderately strong HCl, but is substantially insoluble in water.

DETERMINATION OF SILVER IN ORES AND CON-CENTRATES CONTAINING PLATINUM AND PALLADIUM

Make the usual crucible fusion on one-quarter, one-half or full assay ton, according to the amount of silver present. Instead of cupeling the lead button, hammer it free from slag and dissolve it in dilute nitric acid. Most of the silver passes into solution together with palladium, and perhaps a trace of platinum; but gold and most of the platinum remain insoluble. The gold and platinum retain an appreciable proportion of silver which cannot be washed out. Filter out the insoluble residue and wash it thoroughly with hot dilute nitric acid, followed by hot water. Scorify the residue once more with a little lead and dissolve the lead button as before, filtering into the beaker containing the first filtrate. In this liquid precipitate the silver as AgCl by adding standing NaCl in sufficient quantity; stir well, and if the amount of silver is small, add about ½ cc. of strong H₂SO₄ to form a precipitate of lead sulphate. Let the silver chloride, or the silver chloride plus lead sulphate, settle over night or until the supernatant liquid is clear; filter through double filter papers; ignite and scorify the residue of silver chloride with test lead.

If the amount of palladium contained in the sample is small, the silver bead obtained by cupeling the lead button obtained by scorifying the silver chloride may be considered as sufficiently pure for ordinary purposes. It contains, of course, some palladium, and in accurate silver determinations the lead button from the first silver-chloride precipitation should be redissolved and the silver reprecipitated, filtered and scorified as before. The amount of palladium retained after the second precipitation

and scorification is so small as to be negligible.

SCHEME FOR QUALITATIVE ANALYSIS OF HEAVY METALS AND ALKALINE EARTHS

(The material is either in solution or is capable of being

readily dissolved.)

(A) Slightly acidulate solution with HCl. It is best to take only a small portion of the solution, and if a precipitate forms, see whether it redissolves in more acid. If it does, it indicates Sb or Bi. Permanent precipitate shows Ag, Pb, or Hg (ous).

Filter precipitate (B) and reserve solution (C).

(B) Wash with hot water, and add K₂Cr₂Ó₇ solution to filtrate. Heavy yellow precipitate shows lead. Wash residue (B) with NH₄OH, and acidulate filtrate with HNO₃. Precipitate shows Ag. Blackening of filter paper shows Hg (ous). (C) Pass in H₂S until precipitate coagulates. Precipitate may be As (yellow), Sb (orange), Sn" (brown), Sn"" (yellow), Hg' or Hg" (black), Bi (brown), Cd (yellow), Pb (black), Cu (black). Filter, giving precipitate (D) and solution (E). (D) Warm with ammonium polysulphide and filter. Fil-

trate (G) may contain As, Sb, Sn, and traces of Cu. (Also Au, Ir, Se, W, Pt, Te, V, of the rare elements.) Precipitate (E) contains Hg, Bi, Cd, Pb, Cu.

(G) Throw down precipitate from (NH₄)₂S₂ solution with HCl. Leach precipitate with ammonium carbonate. Filter. Add HCl to filtrate to faint acidity. Pass dissolves. Yellow precipitate shows arsenic. (May be confirmed in H₂S. by Marsh test.) Dissolve remaider of precipitate E in strong HCl. Dilute and add metallic zinc in contact with a small piece of platinum. Precipitate of metallic tin and antimony Treat with HCl and filter. To filtrate add HgCl2 solution. White to gray precipitate of Hg₂Cl₂ shows tin. Treat residue from extraction with aqua regia, boil off excess Cl and HNO₃, and pass in H₂S. An orange precipitate of Sb₂S₄ confirms the presence of antimony, already indicated by a blackening of the platinum.

(F) Heat residue from ammonium polysulphide leaching with dilute (10 per cent.) HNO, and filter. Heat residue with concentrated HNO₃, dilute and filter, combining the two filtrates. The precipitate (H) remaining consists of HgS and S. filtrate (I) contains Cd, Bi, Cu, Pb.1 (If the original treatment is made with concentrated HNO₈ all of the PbS may be oxidized to PbSO₄ and remain with the mercury. PbŠ is soluble in 10 per cent. HNO₂ according to the equation PbS

 $+2HNO_3 = Pb(NO_3)_2 + H_2S$).

(H) Dissolve precipitate in aqua regia. Boil off excess of Cl and HNO₃ and add SnCl₂. A white to gray precipitate confirms presence of mercury, probably already indicated by the black residue from the HNO₃ leaching.

(I) Add a few drops of H₂SO₄ to solution. White precipitate indicates lead. Filter, getting precipitate (I) and

solution (K).

(J) Treat precipitate on filter with hot ammonium acetate and filter, adding K2Cr2O, to filtrate. Chrome-yellow pre-

cipitate confirms presence of lead.

(K) Evaporate to small bulk, add about eight times bulk of alcohol, warm, and filter (to ensure removal of all lead). Evaporate off alcohol on sand bath and make strongly ammoniacal. White precipitate indicates Bi. Blue solution indicates Cu. The blue may be so intense as to mask the Bi(OH), precipitate. Filter and wash, and treat filter paper with strong HCl, catching strong HCl solution in a beaker. Dilute largely. precipitate shows Bi. Take blue copper solution and add KCN solution until blue color just disappears and pass in H₂S. Bright-yellow precipitate indicates Cd.

(E) Boil off all H₂S from the filtrate from the H₂S precipitation, making sure finally that it is all gone by adding a few drops of HNO, and boiling. If organic acids, tartaric, citric, or the like are present, it is best to destroy them by evaporating almost to dryness and adding some concentrated

¹ Pd and Os belong in the H2S group of metals whose sulphides are insoluble in (NH₄)₂S₂.

H₂SO₄ and fuming HNO₃. Test a little of the solution for phosphoric acid by means of ammonium-molybdate solution in nitric acid. If a yellow precipitate shows phosphates, evaporate to a thick soup, and add a little tin and nitric acid and boil until action ceases. Dilute, filter, and repeat. The phosphorus is removed as stannous phosphate, all but traces of the tin remain undissolved as metastannic acid. If only traces of the further groups of metals are being looked for, boil off all the nitric acid with repeated additions of HCl, throw out the last of the tin with H₂S, filter, then boil off the H₂S and remove the last traces of it with HNO₃, as above specified. If phosphorus is not present, all of this is unnecessary. Add a little NH₄Cl and make the solution ammoniacal. Fe, Al and Cr are precipitated (L). Boil off excess of ammonia, filter; solution (M) contains Co, Mn, Ni and Zn and the alkaline earths and alkalis.

(L) Leach precipitate with hot KOH solution. Make leachings acid with HCl and add ammonia. White flocculent precipitate indicates alumina. Dissolve half of original precipitate with HCl and add K₄FeCy₆. Precipitate of Prussian blue confirms presence of iron, probably already indicated by red color of precipitate. Take the other half of the precipitate and fuse with sodium carbonate and sodium nitrate. A yellow melt indicates sodium chromate. Dissolve melt in water, acidify with acetic acid and add a drop of lead-acetate solution. Precipitate of lead chromate confirms presence of chromium, probably already indicated by a greenish hydroxide precipitate

or the yellow melt.

(M) Pass in H₂S into solution. Mn, Zn, Co, Ni precipitate. Filter. Filtrate (N) contains alkalies and alkaline earths. Treat precipitate with cold dilute HCl. Mn and Zn dissolve. Add KOH in excess. Filter, acidify filtrate with acetic acid and pass in H₂S. A white or nearly white flocculent precipitate confirms the presence of Zn. Take the precipitate from the KOH precipitation and fuse with Na₂CO₃ and NaNO₃. A green melt shows manganese. Take the residue insoluble in HCl and touch a borax bead to it and heat. A bead, violet when hot, blue when cold, shows cobalt. A gray bead (cold) shows Ni only, but this is easily masked by cobalt blue. So if the bead is blue, dissolve the residue in aqua regia, evaporate to soup, dilute, and add KCN until the precipitate first formed redissolves. Heat solution gently, add a little NaOH, then Br (under a hood). A black precipitate shows nickel.

(N) Boil until H₂S odor becomes faint, add NH₄OH and (NH₄)₂CO₃ and warm slightly. Ba, Sr, and Ca precipitate. Filter and dissolve precipitate in HCl. Add H₂SO₄ to part of the solution. Precipitate indicates Ba or Sr or both. To another part of the solution add K₂CrO₄. An immediate precipitate of a pale yellow color shows Ba. In the filtrate Sr can be

¹ The hydroxide precipitate will carry down As, Sb, Se, Te, Sn, P and Ti if they are present, which reaction affords an easy way to concentrate these elements from a large bulk of copper in exact copper analysis.

determined by the reddish color given a Bunsen burner flame, while Ca can be precipitated as calcium oxalate (white) in ammoniacal solution. Calcium colors a Bunsen flame reddish yellow, and Ba a vivid green.

(0) Add ammonium or sodium-phosphate solution to the filtrate from the Ba, Ca, Sr precipitation. Stir, cool, and allow to settle over night. Granular white precipitate shows Mg.

Qualitative Tests for Acids¹

The acid-radicals cannot be advantageously precipitated in groups, and the members separated and identified as with the metals. They are usually detected in the course of analysis by special tests. They may, however, be arranged in groups of such acid-radicals as resemble one another. A consideration of the metals present, in case the material is in solution, will often rule out many acids as possibilities at once.

The acids may be arranged as follows:

Group I.—Acids which are precipitated by AgNO₃ in presence of nitric acid.

Hydrosulphuric acid	H_2S
Hydrochloric acid	HCl
Hydrobromic acid	HBr
Hydriodic acid	\mathbf{HI}

Group II.—Acids whose salts deflagrate on charcoal.

Nitric acid HNO₃ Chloric acid HClO₃

Group III.—Acids which cannot be classified.

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Boracic acid	H_aBO_a
Carbonic acid	H_2CO_3
Chromic acid	H_2CrO_4
Hydrofluoric acid	HF
Phosphoric acid	$H_{2}PO_{4}$
Silicic acid	H ₄ SiO ₄
Sulphuric acid	H_2SO_4
Arsenic acid	H ₂ AsO ₄
Hydrocyanic acid, acetates	HCN

GROUP I

H₂S.—AgNO₃ gives a black pp. of Ag₂S insoluble in dilute acids.

Lead acetate—a black pp. of PbS insoluble in dilute acids. Dilute HCl—many sulphides when heated with dilute HCl evolves H₂S, which blackens paper moistened with lead acetate. If much H₂S is present, there will be the characteristic odor present, but do not smell the gas coming off unless you are sure no cyanides are present. It is safer to have some one else smell it, anyway.

¹James Park, "A Text-Book of Practical Assaying," with some original additions.

HCl.—AgNO₃—a white pp. of AgCl at first white, turns violet on exposure to light. Readily soluble in ammonia and KCN. Insoluble in dilute nitric acid.

Lead acetate—a white pp. of PbCl₂ soluble in hot water.

Strong H₂SO₄—when heated with dry chlorides causes evolution of HCl gas, chlorides of Hg and Sn excepted. Bromides, iodides, fluorides, cyanides, carbonates, sulphides, sulphites, thiosulphates and acetates also give off characteristic gases during this test.

MnO₂ + H₂SO₄—when mixed with a chloride causes evolution of chlorine, which bleaches wet litmus paper or a green leaf. Iodine and bromine are also evolved by this means. The

colors are characteristic.

HBr.—AgNO₈—a yellowish-white pp. of AgBr; sparingly soluble in ammonia but readily in KCN. Insoluble in dilute nitric acid. Phosphates also give a yellow precipitate. Test for phosphoric acid with ammonium molybdate in HNO₃ solution.

Lead acetate—a white pp. of PbBr₂.
Strong H₂SO₄—with a dry bromide causes evolution of HBr

MnO₂ + H₂SO₄—causes evolution of Br, which turns starch

paper yellow.

Chlorine water or HCl + two drops of NaClO, when added, drop by drop, to a solution of a bromide liberates Br, which colors solution orange red. Avoid excess of Cl, as it destroys color. When a portion is warmed, reddish-brown vapors are given off. If three drops of CS2 are added, the Br will sink to the

HI.—AgNO₃—a yellowish-white pp. of AgI. Sparingly soluble in ammonia; readily in KCN. Insoluble in dilute nitric acid.

Lead acetate—bright yellow pp. of Pbl₂. Chlorine water—reacts for iodine, giving a brown solution and violet vapors. To a portion add starch solution, an intense blue is produced.

GROUP II

Nitric Acid (Nitrates)1

Dry Reactions.—1. If a nitrate is heated on charcoal it deflagrates, the charcoal burning at the expense of the O of the nitrate. Nitrites, chlorates, chromates, manganates and permanganates also give this reaction.

2. If a mixture of a nitrate and KCN powder be heated on platinum foil, deflagration takes place. This is a delicate test.

Wet Reactions.—1. Strong H₂SO₄ heated with nitrates causes evolution of fumes of nitric acid. Nitrites give this reaction.

2. Mix sol. of a nitrate with strong sol. of FeSO₄. Hold test-tube in a slanting position and pour strong H₂SO₄ down to

¹ Nitrites also give most of these reactions.

bottom. A purple or brown color will mark the plane of contact of the fluids. Nitrites also give this and the following reaction.

3. Copper filings and H₂SO₄ heated with a nitrate liberate NO, which becomes peroxidized to NO₂ on contact with the air.

4. A sol. of indigo boiled with HCl and a sol. of a nitrate decolorized. Not characteristic, as chlorine reacts the same. 5. A little brucine dissolved in H₂SO₄ when added to a sol. is decolorized.

of a nitrate gives a fine red color. This is a very delicate test.

6. Free nitric acid may be detected by evaporating to dryness with quill-cuttings. These will be colored yellow.

It gives with FeSO₄ a brown ring; and with copper filings or

foil a reddish-brown gas, NO2, and a blue color.

The most delicate test for nitrates is to take 2 or 3 c.c. of the solution in HCl, add 12 drops of a solution of diphenylamine in sulphuric acid, then run in H₂SO₄ below the mixture. blue will be given by 1 part in 1,000,000 of HNO₃.

Chloric Acid (Chlorates)

Dry Reactions.—1. Chlorates when heated on charcoal deflagrate far more violently than nitrates. So do perchlorates.

2. Heated on charcoal with KCN, chlorates detonate violently. Use only small quantities in this experiment.

Wet Reactions. -1. A few drops of H₂SO₄ added to a small quantity of a chlorate liberate chlorine peroxide (ClO₂), which colors the H₂SO₄ intensely yellow, and has a strong odor of Cl and a greenish color. This experiment should be tried in a watch-glass without heat, as an explosion might take place.

2. If a cold sol. of indigo is added to a cold sol. of a chlorate till distinctly blue, and some H₂SO₄ then poured in and shaken, the blue color of the indigo is at once destroyed. Chlorites,

perchlorates, and hypochlorites also give this reaction.

3. If a chlorate is mixed with Na₂CO₃ and ignited, O₂ is given off and a chloride remains. On dissolving the residue, acidifying with nitric acid, and adding silver nitrate, a white pp. of AgCl is formed.

GROUP III

Boracic Acid

Dry Reactions.—1. Boric acid tinges the Bunsen flame green.

2. Pour some methylated spirits on finely powdered borax in a porcelain dish; add a little H2SO4; mix and ignite; the

flame will show a green edge.

Wet Reactions.—1. If a sol. of an alkaline borate is mixed with HCl to slight but distinct acid reaction, and a strip of turmeric paper is half dipped into it and then dried at 212°F. (100°C.), the dipped half will show a peculiar red color-very delicate. Sodium carbonate turns this to a dark blackish-green, and HCl will restore the color.

Carbonic Acid

Wet Reactions.—1. Almost any acid when poured on a carbonate in a test-tube causes effervescence due to rapid evolution of CO₂. When conducted into lime-water this gas causes a pp. of CaCO₃, which is sol. in large excess of the gas. Cyanides, sulphites, tellurides, selenides, sulphides, and thiosulphates also effervesce. Be careful about inhaling these gases.

Chromic Acid

Dry Reactions.—1. Compounds of chromic acid give an emerald-colored bead with borax on platinum loop in both

outer and inner blowpipe flames.

)

Wet Reactions.—1. H₂S added to an acidified sol. of a chromate produces a green coloration due to reduction of the chromic acid [CrO₈]. A white precipitate of sulphur is formed at the same time.

(Readily oxidizable substances deoxidize K₂Cr₂O₇ with production of a chromic salt; the color of the solution at the same

time changes from orange red to bright green.)

- 2. H₂O₂ or BaO₂ if added to a *cold* acidified sol. of a chromate produces an intense blue coloration, which becomes fixed if *ether* is *first* added and the liquid well shaken after adding the peroxide. The ether assumes and retains the blue color. A few drops of HNO₃ are useful. This is an extremely delicate and characteristic test.
- 3. BaCl₂ gives a light yellow pp. of BaCrO₄, sol. in HCl and HNO₃.

4. AgNO₃ gives a dark purple-red pp. of Ag₂CrO₄, sol. in

KNO₃ and NH₄OH.

5. Pb(C₂H₃O₂)₂ gives a yellow pp. of PbCrO₄, sol. in KOH, but insol. in C₂H₄O₂. This precipitate, "chrome yellow," is very characteristic.

very characteristic.
6. If insoluble chromates are fused with Na₂CO₃ and KNO₃, alkaline chromates will be formed, which are soluble in water.

Hydrofluoric Acid

The ordinary tests for a fluoride depend on the liberation of HF, which is allowed to etch glass.

1. If strong H₂SO₄ is warmed with a little finely powdered

CaF₂ in a test-tube, HF is liberated.

2. Cover the convex side of a watch-glass with melted paraffin or wax. Trace lines near the middle of the glass with the point of a penknife so as to remove the wax from these parts, but not to scratch the glass. Place the prepared glass on the top of a platinum crucible containing a little finely powdered CaF₂ and some strong H₂SO₄. Pour a few drops of water into the watch-glass to keep it cool, and gently heat the bottom of the crucible. Allow to stand for 20 minutes. Melt off wax, and on the clean surface the etched lines will be visible. If small

traces of a fluoride were present, the tracing will become visible by breathing on the cold surface of the glass.

This reaction fails when there is too much SiO₂ present, as

the H₂SO₄ then liberates SiF₄ instead of HF.

SiF₄ does not etch glass, but produces white fumes in moist air; when these fumes are conducted into water a colorless flocculent pp. of gelatinous silica is separated.

$$H_4SiO_4 = SiO_2 + 2H_2O$$

3. CaCl₂ when added to the solution of a fluoride gives an almost transparent gelatinous pp. of CaF₂, which becomes more visible when the liquid is heated or when ammonia is added.

Phosphoric Acid

Wet Reactions.—1. MgSO₄ solution (to which ammonium chloride has been added and then a little ammonia) gives with the solution of a phosphate a white crystalline pp. of magnesium ammonium phosphate (MgNH₄PO₄ + 6H₂O) which rapidly settles. This pp. is insol. in NH₄OH, but is readily sol. in acids, even $C_2H_4O_2$. If very little phosphate is present, the pp. often appears only after the solution has been warmed and allowed to stand.

2. Silver nitrate throws down from neutral solutions a light yellow pp. of Ag₂PO₄, readily soluble in nitric acid and ammonia.

3. The solution of ammonium molybdate in nitric acid gives in the cold a finely divided yellow pp. which settles rapidly. With small quantities of a phosphate, a few hours must be allowed for the reaction, and the liquid may be warmed gently, but not above 40°C. (104°F.). Not more than an equal volume of the fluid to be tested should be added to the molybdate. Large quantities of HCl interfere with the precipitation.

The pp. after subsiding may be separated by filtering, washed with ammonium molybdate solution, then dissolved in ammonia, and, by adding NH₄Cl and MgSO₄ as in (1), the pp.

of MgNH₄PO₄ + 6H₂O may be obtained.

The solution to be tested must not be alkaline to test paper, but should be made distinctly acid with HNO₃. It should then be added in *small quantities* only to some NH₄HMoO₄ sol. in a test-tube, more being added if no yellow pp. forms after a few minutes, when the liquid may be gently warmed.

Arsenates

The pps. found in (1) and (3) with a phosphate are precisely the same as those formed when an arsenate is present. AgNO₃ gives with an arsenate a brown pp.; with a phosphate a yellow pp.; and ammonium molybdate solution gives a pp. with an arsenate only after boiling instead of gently heating as with a phosphate. It is also possible to remove the arsenic with H₂S in HCl solution before making confirmatory tests for phosphates.

Silicic Acid

Dry Reaction.—1. If a fragment of silica or a silicate is heated in a bead of microcosmic salt, it remains undissolved and floats about in the bead as a more or less transparent mass, which retains its original shape. In the case of a silicate the bases dissolve out.

Wet Reactions.—2. NH₄Cl produces in not too dilute solutions

of alkaline silicates a pp. of hydrated SiO₂.

3. The solutions of alkaline silicates are decomposed by all acids, the SiO₂ separating as the gelatinous hydrate. The acid should be added drop by drop and the solution stirred.

Sulphate Group

Remarks.—Sulphates are the only commonly occurring salts which give with BaCl₂ a pp. insoluble in boiling HCl. (Selenates also give a pp. of BaSeO₄ with BaCl₂, but it dissolves on boiling with strong HCl for some time.)

Tests for Sulphates (SO₂, and a Base)

Wet Reactions.—1. All solutions of the sulphates give with BaCl₂ a white pp. of BaSO₄ which is insoluble in all acids.

2. If a sulphate or any solid substance containing sulphur is mixed with pure solid Na₂CO₃ and fused on charcoal in the

inner reducing blowpipe flame, it will yield Na₂S.

Detach the cold fused mass with the point of a knife, place a portion on a bright silver coin, and moisten with H₂O. Allow to remain a short time, and then rinse off; a black stain of Ag₂S will be seen upon the coin, if sulphur is present.

3. Lead acetate produces a heavy white pp. of PbSO₄, which dissolves readily in hot strong HCl, or alkaline acetates.

4. Sulphuric acid gives, with sugar, a black mass.

5. To detect free sulphuric acid, mix the fluid with a very little cane-sugar and evaporate to dryness at 212°F. (100°C.). If any is present, a black residue will remain; or with small traces a blackish-green residue. No other free acid decomposes cane-sugar in this way.

Cyanides and Acetates

Cyanides.—These give a blue color with a mixture of ferrous and ferric salts.

Some additional tests for other acids are:

A concentrated solution in hydrochloric acid will, when H₂S is passed in, give a precipitate of sulphur if it contains nitrates, nitrites, chlorates, sulphites, thiosulphates, arsenates, chromates, manganates or permanganates.

Acetates evolve a characteristic odor when present in large quantity in strong sulphuric-acid solution. They give blood-red solution with ferric salts. If the solution be neutral

the iron is precipitated on boiling.

SOME PROPERTIES OF RADIOACTIVE SUBSTANCES

The table below is based on tables in Le Radium, Jan., 1909, Jan., 1910 and Jan., 1911, and in Zeit. für Angew. Chemie. July 6, 1915. See also pages 239–253.

0, 1910. 56	e also pages 259-255.
SUBSTANCE	Properties
U	Sol. in excess of am. carb. Nitrate soluble in ether and acetone. Atomic weight, 238.2. Half-decay period, 5 × 10° years. Gives off ∝ particles.
UX	Carried down by BaSO ₄ . Soluble in HCl. Less volatile than U. Volatile in electric arc. Insoluble in excess of am. carb. Soluble in water and ether. Half-decay period, 24.6 days.
UY .	Carried down by barium sulphate, with moist ferric hydrate, and by animal charcoal. Half-decay period, 1.5 days.
Io	Soluble in excess of am. oxalate. Carried down by H ₂ O ₂ in presence of U salts. Half-decay period, over 2 × 10 ⁵ years (?). Gives off ∝ particles.
Ra	Characteristic spectrum. Spontaneously luminous. Analogous to Ba. RaCl ₂ and RaBr ₂ are less soluble than BaCl ₂ and BaBr ₂ . Atomic weight, 226.4. Half-decay period, 2000 years.
\mathbf{RaEm}	One of group of inert gases. Characteristic spec-
(Niton)	trum. Mol. wt. = 218. Half-decay period, 3.85 days. α particles.
RaA	Behaves as a solid. Deposited on cathode in an electric field. Volatile at 800-900°C. Soluble in strong acids. Half-decay period, 3 min.
RaB	Like RaA. Volatile at 400-600°C. Precipitated by BaSO ₄ . Half-decay period, 26.8 min.
RaC	Physically like RaA. Volatile at 800-1300°C. Chemically like RaB. Deposited on Cu and Ni. Perhaps mixture of two products. 19.5 min.
RaD	Volatile below 1000°C. Soluble in strong acids. Reactions of RaD and RaE ₁ analogous to those of Pb. Sometimes known as radiolead.
$\mathbf{RaE_1}$	Volatile at red heat. Soluble in cold acetic acid.
$\mathbf{RaE_2}$	Not volatile at red heat. Reactions similar to Bi.
RaF	Volatile toward 1000°C. Deposited from its solu-
(Polonium.)	PbCO ₃ , and by SnCl ₂ with Hg and Te. RaD, E ₁ , E ₂ , and F can be separated by electrolysis. 136 days, breaks down to lead.
Ac	Produces helium. Precipitated by oxalic acid in acid solutions. Oxalate insoluble in HF; accompanies thorium and rare earths. Unknown period. α particles. Same as emanium.
Rad. Ac	Slightly volatile at high temps. Insoluble in NH ₄ OH. Separated from Ac by electrolysis, by fractional precipitation, by ammonia, and by

animal charcoal. Half-decay period, 19.5 days. ∝. Discovered by Hahn.

AcX Deposited by electrolysis in alkaline solution.

Not precipitated by NH₄OH. 10.5 days.

AcEm Behaves as inert gas. Coef. of diffusion in air 0.11. Condenses at -120°C. Half-decay, 3.9 sec.

AcA Volatile below 400°C. Soluble in NH₄OH and strong acids. Half-decay, 36 min. Rayless.

AcB Volatile below 700°C. Soluble in NH₄OH and strong acids. Deposited by electrolysis of active deposits on cathode in HCl. Half-decay, 2 min.

Rad. Th Carried down by hydrates, precipitated by NH₄-OH. Separated by Hahn and much more active than thorium, and it may be a small contamination of this element gives out the rays in the thorium transformation and that the thorium transformation is in reality rayless. α rays.

ThX Soluble in NH₄OH. Carried down by iron. Deposited by electrolysis in alkalis. 4 days.

ThA Volatile under 630°C. Soluble in strong acids.

ThB Volatile below 730°C. Like ThA. Deposited on Ni. Separated from ThA by electrolysis. 55 min. α, β, γ particles.

ThC Like ThB. Probably two products.

One gram of radium gives off 0.0328 cal. per sec., and produces 5.17×10^{-9} cc. of helium (0°, 76 cm. pressure) per gram per sec.

Heats of Formation

Heats of formation are expressed in calories, *i.e.*, the amount of heat necessary to raise 1 gram of water from 10°C. to 11°C. When it is said that the heat of formation of any compound is a certain number of units, it is meant that this number of calories is developed in the production of a mass in grams of the substance equal to its molecular weight, *i.e.*, when we say that $C + O_2 = CO_2$ 97,200 cal.

we mean that 12 grams of carbon and 32 of oxygen develop

97,200 cal.

The heat of formation and the heat of decomposition of any substance are the same; i.e., in order to effect the decomposition of a substance an amount of heat must be supplied equal to the amount evolved in the formation.

The heat of combination of the elements, like many others of their properties, follows the periodic law, the relation being thus stated by W. G. MIXTER $(Am.\ Journ.\ Sci.,\ June,\ 1914)$: The heat equivalents of the elements of a subgroup in the series

III to VIII are either linear functions of the atomic weights, or the heat of formation of the oxide of the middle member falls below the linear value by a constant amount for each atom of oxygen combined.

HEAT OF FORMATION OF SILICATES

Starting from	Gram- cal. per molecule	Gram- cal. per gram of silicate formed	Starting from	Gram- cal. per molecule	Gram- cal. per gram of gilicate formed
FeO, SiO ₂	10,600 5,400 14,700 17,850 28,300 28,550 17,900 14,900 33,500 45,200 45,200 4,50 3,300 2,950	80 41 69 154 165 125 110 67 86 170 720 370 3 15	Fe, Si, Oz Mn, Si, Oz Ba, Si, Oz Ca, Si, Oz Cas, Si, Oz Cas, Si, Oz Csz, Si, Oz Sr, Si, Oz Alz, Siz, Or Cas, Als, Siz, Oz Lis, Siz, Oz Nez, Si, Oz Ca, Alz, Oz Ca, Alz, Oz Ca, Alz, Oz Ca, Alz, Oz Ca, Alz, Oz Ca, Alz, Oz	254,600 276,300 328,100 329,350 471,300 603,050 329,100 767,500 1,195,550 927,420 347,100 326,100 524,550 658,900 789,050	2,109 1,540 2,839 2,740 2,645 2,019 3,457 3,065 3,555 3,856 2,673 3,220 3,079
27, Al ₂ O ₃ 9.2, Cu 0.42, S 0.42 per cent.	}	100	 		
2FeO, SiO ₂ FeO 70.80, SiO ₁ 29.20 per cent FeO 57 58, CaO 12.90, SiO ₂ 30.42		109	Fes, 81, Os	(SEE) LANS	1,637
FeO 40.30, CaO		140			
28.00, SiO; 31 70 per cent		198			

HEATS OF FORMATION OF MIXTURES OF SIO, CaO, AND AN-HYDROUS KAOLIN

The kaolin used in these experiments was: SiO₂, 53.58 per cent., Al₂O₄, 43.40, Fe₂O₄, 1.25. The difference between the sum of the Al₂O₄ and CaO and 100% is the SiO₂.

Al ² O ³ per cent. CaO per cent.	2	100	20	30
10 20 30 40 50	+ 76.1 +103.2 +150.6 +154.0	+ 42.8 + 69.7 +109.0 +135.8 +180.4	+ 19.2 + 47.9 + 82.3 +106 5 +137.8	+ 1.7- +49.9 +73.0

¹ Revne de Metallurgie, 1913, p. 673.

HEAT OF FORMATION OF OXIDES

	LEAT OF TORMAIL		
Formula	Molecular weights	Molecular heat of formation	In dilute solution
34			
Mg, O	$ 24 + 16 = 40 \\ 137 + 16 = 153 $	143,400 133,400¹	148,800 161,500
Ca, O	40+16=56	131,500	149,600
Sr, O	87+16=103	131,200	158,400
Al2. O2.	54 + 48 = 102	392,600	
Ti, O ₂	48 + 32 = 80	218,500	
Na ₃ , O	46+16=62	100,900	155,900
K ₂ , 0	78 + 16 = 94	98,200	165,200
Si, O ₂	28 + 32 = 60	180,000	180,000¢
Mn, O	55+16=71	90,900	
B2, O2	22 + 48 = 70	272,600	279,900
Z n, O	65+16=81	84,8002	82,680
$\mathbf{Mn}_{2}, \mathbf{O}_{4}$	165+64=229	328,000	405,000
$\mathbf{P}_2, \mathbf{O}_5 \dots$	62+80=142	365,300	
8n, 0	$ \begin{array}{c} 118 + 16 = 134 \\ 118 + 32 = 150 \end{array} $	70,700 141,300	••••••
$\operatorname{Sn}, \operatorname{O}_2 \ldots$	$ \begin{array}{c} 110 + 32 = 150 \\ 28 + 16 = 44 \end{array} $	68,040	73,940
CO , 0	20+10-12 $2+16=18$	70,400 solid	10,040
H ₂ , O	2+10-18 2+16=18	69,000 liquid	
<u></u>	2+16=18	58,060 gas	
H ₂ O ₂ ³	2 + 32 = 34		47,300*
Fez, O4	168 + 64 = 232	270,800	
Cd, O	112 + 16 = 128	66,300	
Fe, O	56+16=72	65,700	
Fe2, O3	112 + 48 = 160	195,600	
C o, O	59+16=75	64,100	
Mn, O_2	55+32=87	125,300	
Ni, 0	58.5 + 16 = 74.5	61,500	
Sb_2, O_2	240 + 48 = 288	166,900	148,900
A82, O ₃	$ \begin{array}{c} 150 + 48 = 198 \\ 207 + 16 = 223 \end{array} $	156,400 50,800	i '
Pb, 0	$ \begin{array}{c cccccccccccccccccccccccccccccccccc$	97,200 gas	103,100
C, O ₂	416+48=464	139,2004	
Sb ₂ , O ₅	240 + 80 = 320	231,200	
AB2, O6	150 + 80 = 230	219,400	225,400
Cu ₂ , O	127.2 + 16 = 143.2	43,800	
Tl ₂ , O	408 + 16 = 424	42,800	39,700
Cu, O	63.6 + 16 = 79.6	37,700	
Ba, O ₂	137 + 32 = 169	145,500	
8 , 0 ₂	32+32=64	69,260 gas	77,600
Pb, O ₂	207 + 32 = 239	63,400	141 000
8, 0	32 + 48 = 80 $408 + 48 = 456$	91,900 ⁵ 87,600	141,000
Tl_2, O_3, \ldots	12+16=28	29,160 gas	
C, O	400+16=416	22,200	
Hg, O	200 + 16 = 216	21,500	
Te, O ₂	125.5 + 32 = 157.5		78,300
P d, O	106+16=122	21,000	
Pt, 0	195 + 16 = 211	17,000	
Ag ₂ , O	216+16=232	7,000	
Au2, O3	394 + 48 = 442	-11,500	
N_2, O	28+16=44	-19,000	
Ŋ, O	14+16=30	-21,6006	
N ₂ , O ₃	28 + 48 = 76	$\begin{array}{c c} -21,400^{6} \\ -1,700^{6} \end{array}$	
N, O ₂ (at 22°)	$ \begin{array}{c c} 14 + 32 = 46 \\ 14 + 28 = 42 \end{array} $	-7.600°	
$N, O_2 \text{ (at } 150^{\circ})$	$ \begin{array}{c cccccccccccccccccccccccccccccccccc$	1	3,6004
N ₂ O ₃	266 + 16 = 282	100,000	0,000
Li ₂ O	14+16=30	140,000	
Rb ₂ O	171 + 16 = 187	94,900	
W, O ₂	184 + 48 = 232	243,000	
V ₂ , O ₅	102 + 80 = 182	441,000	
Cr2. O3	104 + 48 = 152	266,0007	l
1 THOMSEN, 126.0		25°C. * "Annuai	re des Bureau des

¹ THOMSEN, 126,000. 242,740 at 1125°C. "Annuaire des Bureau des Longitudes," 1914. 4 KAYE and LABY, 20,000. 5 KAYE and LABY, 103,000. THOMSEN, "Thermochemistry."

7 This is the heat evolved by a stable amorphous oxide. There is an unstable form evolving only 243,000 cal.

HEAT OF FORMATION OF HYDROXIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Li, O, H. Mg, O2, H2. Sr, O2, H2. Ca, O2, H2. K, O, H. Na, O, H. Na, O, H. N, O, Ha. Al, O4, H4. Tl, O, H. Bi, O4, H4. Zn, O2, H2. Te, O2, H2. Te, O3, H3. Se, O4, H4. Se, O4, H4. Se, O4, H4. Ba, O2, H2. Cd, O2, H2. Cd, O1	24+32+2=58 87+32+2=121 40+32+2=74 39+16+1=56 23+16+1=40 18+16+1=35 27+48+3=78 1+16+1=18 204+16+1=221 208+48+3=259 65+32+2=99 127+32+2=161 127+48+3=178 79+32+2=113 79+48+3=130 204+48+3=255 137+32+2=171 112+32+2=146	112,300 217,800 217,300 215,600¹ 104,600 102,700 88,800 301,300 { 70,400 solid 69,000 liquid 58,060 gas 57,400 171,700 83,500 78,300 99,500 52,400 79,300 43,800 217,000² 66,000² 101,300 102,000	118,110 227,400 219,500 117,100 112,500 90,000 54,300

HEAT OF FORMATION OF CYANIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Ca, C2, N2. K, C, N. Na, C, N. K, Ag, C2, N2. Cer, C18, N18. Cn, C2, N2. Cd, C2, N2. Cd, C, N. Cd, C2, N2. H, C, N. Hg, C2, N2.	39 + 12 + 14 = 65 $23 + 12 + 14 = 49$ $39 + 108 + 24 + 28 = 199$ $392 + 216 + 252 = 860$ $65 + 24 + 28 = 117$ $112 + 24 + 28 = 164$ $63.6 + 12 + 14 = 89.6$ $106 + 24 + 28 = 158$	33,450 25,950 13,700 -256,700 -24,550 -31,850 -20,375 -49,250 -27,150 (gas) -59,150	41,650 30,250 25,450 5,350 -21,050

HEAT OF FORMATION OF CYANATES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
K, C, N, O Na, C, N, O Ag, C, N, O	39+12+14+16=81 $23+12+14+16=65$ $108+12+14+16=150$	105,850 105,050 26,450	100,650 100,250

¹ Kave and Laby, 229,000. ² Thomsen, "Thermochemistry."

HEAT OF FORMATION OF FERROCYANIDES

Formula .	Molecular weights	Molecular heat of formation	In dilute solution
Fe, Ce, Ne	156+56+72+84=368	157,300	145,300
Fe, Cs, Ns	117 + 56 + 72 + 84 = 210 $117 + 56 + 72 + 84 = 329$	129,600	-101,500 $100,800$ $-127,400$
	Fe, Cs, Ns Fe, Cs, Ns	Fe, C ₆ , N ₆ $156+56+72+84=368$ Fe, C ₆ , N ₆ $4+56+72+84=216$	Formula Molecular Weights of formation Fe, C ₆ , N ₆ $156+56+72+84=368$ Fe, C ₆ , N ₆ $4+56+72+84=216$ $-102,000$

HEAT OF FORMATION OF SELENIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
i 2, Se	14+79=93	83,000	93,700
S ₂ , Se		79.600	87,900
a, Se	137 + 79 = 216	69.900	
r, Se	87 + 79 = 166	67,600	1
a, Se	40 + 79 = 119	58,000	
a ₂ , Se	46 + 79 = 125	60,900	78,600
n, Se		30,300	
d, Se	112 + 79 = 191	23,700	
[n, Se	55 + 79 = 134	22,400	
, H ₅ , Se	14+5+79=98	17,800	12,800
u, Se	63.6 + 79 = 142.6	17,300	
b, Se	207 + 79 = 286	17,000	
e, Se	56+79=135	15,200	
i, Se	58.5 + 79 = 137.5	14,700	
o, Se	59 + 79 = 138	13,900	[
l :, Se		13,400	
u2, Se	127.2 + 79 = 206.2	8,000	
g, Se	200 + 79 = 279	6,300	1
g₂, Se	216 + 79 = 295	2,000	
2, Se	2+79=81	-25,100 (gas)	-15,800
, Se	14+79=93	-42,300	

HEAT OF FORMATION OF TELLURIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Zn, Te. Cd, Te. Co, Te. Fe, Te. Ni, Te. Cli, Te. Cui, Te. Pb, Te. Hi, Te.	112+126=238 $59+126=185$ $56+126=182$ $58.5+126=184.5$ $408+126=534$ $127.2+126=253.2$ $207+126=333$	31,000 16,600 13,000 12,000 11,600 10,600 8,200 6,200 -34,900 (gas)	

HEAT OF FORMATION OF SULPHIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Li ₂ , S	14 + 32 = 46		115,400
K_2, S_{\cdots}	78 + 32 = 110	103,500	113,500
Ba, S	137 + 32 = 169	102,900	109.800
Sr, S	87 + 32 = 119	99,300	106,700
Ca, S	40 + 32 = 72	94,300	100,600
Na ₂ , 8	46 + 32 = 78	89,300	104,300
Mg, S	24 + 32 = 56	79,400	
K, S ₂	39 + 64 = 103	59,300	59,700
Na, S ₂	23 + 64 = 87	49,500	54,400
Mn, S	55 + 32 = 87	45,600	
Zn, S	65 + 32 = 97	43,000	
M2, S3	54 + 96 = 150	126,400	
N, Hs, S	14+5+32=51	40,000	36,700
Cd, S	112 + 32 = 144	34,400	
32, S2	22 + 96 = 118	75,800	
Te, S	56+32=88	24,000	• • • • • • • • • •
Co, S	59 + 32 = 91	21,900	
[l ₂ , S	204 + 32 = 236	21,600	
Cu ₂ , S	127.2 + 32 = 159.2	20,300	
Ъ, 8	207 + 32 = 239	20,200	
Si, S2	28 + 64 = 92	40,000	
Ni, S	58.5 + 32 = 90.5	19,500	
3b2, S2	240 + 96 = 336	34,400	
Ig, §	200 + 32 = 232	10.600	• • • • • • • • • • • • • • • • • • •
ū, š	63.6 + 32 = 95.6	10.100	
I ₂ , S _.	2+32=34	4,800 gas ¹	9,500
Ag2, S	216 + 32 = 248	3,000	3,000
	•	-25 400 gas	• • • • • • • • • • • • • • • • • • •
C, S ₂	12+64=76	$\begin{cases} -25,400 \text{ gas} \\ -19,000 \text{ liquid} \end{cases}$	
្នុ ន	127 + 32 = 159	9,000	••••••
·1 D·····	121 702 - 108	0 ,000	• • • • • • • • • • • •

¹ Molecular heat of combustion of $H_2S = 122,500$ cal., and heat of combustion of 1 cu. meter $H_2S = 5513$ cal.

HEAT OF FORMATION OF NITRIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
C2, N2	3+14=17 $411+28=439$ $21+14=35$ $39+3+14=56$	149,400	-68,300 21,000

¹ F. Haber gives 10,975. Chem. Tr. Journ., Aug. 14, 1915. HEAT OF FORMATION OF METALLIC HYDRIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Sr, H ₂ . Ba, H ₂ . Pt ₁₀ , H. Pd ₁₅ , H. Si, H ₄ . N, H ₂ .	137 + 2 = 139 $1950 + 1 = 1951$ $1590 + 1 = 1591$ $28 + 4 = 32$	38,400 37,500 14,200 4,600 -6,700 ¹ gas 12,200 gas ¹	21,000

¹ F. Haber, 10,975. Chem. Tr. Journ," Aug. 14, 1915.

HEAT OF FORMATION OF PHOSPHIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Mn ₂ , P ₂	$ 165+62 = 227 \\ 3+31 = 34 \\ 56+39 = 95 $	70,900 4,900 nearly 0	

ARSENIDES, ANTIMONIDES, BORATES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
H ₂ , A ₅	3+75=78 $3+120=123$ $46+44+112=202$	44,200 gas86,800 gas 748,100	-36,700 758,300

HEAT OF FORMATION OF FLUORIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Sr, F ₂	87 + 38 = 125	224,020	
Ba, F ₂	137 + 38 = 175	224,000	221,500
Li, F	7+19=26	221,000	116,880
17 T	39+19=58	110,000	113,600
K, F	40+38=78	216,450	•
Ca, \mathbf{F}_2	24+38=62	000'-00	• • • • • • • • • • •
Mg, F ₂			109,120
Na, F	23+19=42	109,720	
N, H4, F	14+4+19=37	101,250	99,750
<u> </u>	27+57=84		275,220
B, F ₈	11+57=68		219,345
Mn, F_2	55 + 38 = 93		153,310
Zn, F ₂	65 + 38 = 103		138,220
3i, F4	28 + 76 = 104	275,920 gas .	
Fe, F ₂	56+38=94		125,220
2d, F ₂	112 + 38 = 150		121,720
Co, F ₂	59 + 38 = 97	[120,340
Ni, F2	58.5 + 38 = 96.5		118,980
Fe, Fa	56+57=113		164,940
n, F	204 + 19 = 223		54,405
Рь, Г	207 + 38 = 245	101,600	02,200
	1+19=20	38,500 gas	50,3001
H, F	120+57=177	· - 1	136,680
3b, F ₈		• • • • • • • • • • • • • •	88,160
Cu, F ₂	63.6 + 38 = 101.6	22,070	
Ag, F	108+19=127	22,070	25,470

¹ Other authorities, 69,000.

HEAT OF FORMATION OF SILICIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Mn ₇ , Si ₂	385 + 56 = 441 $4 + 28 = 32$	47,400 -6,700 gas	

HEAT OF FORMATION OF CARBIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Al4, C3. Mn, C2. Mn, C3. Fe3, C. Ca, C2. Na, C. Li, C. N2, C2. Ag, C. Mn3, C.	55+24=79 $55+36=91$ $168+12=180$ $40+24=64$ $23+12=35$ $7+12=19$ $28+24=52$ $108+12=120$	232,000 . 114,400 9,900 8,460 -6,250 -4,400 -5,750 -73,000 gas -43,575 10,400	-131,500 -67,100

HEAT OF FORMATION OF BROMIDES

Formula :	Molecular weights	Molecular heat of formation	In dilute solution
Na, Br. K, Br. Al, Brs. Zn, Brs. Zn, Brs. Cd, Brs. Cd, Brs. Sn, Brs. Cu, Brs. Ag, Br (cryst.) Sb, Brs. Cu, Brs. Cu, Brs. H, Br. Au, Brs. Au, Brs. H, Br	23 + 80 = 103 $46 + 80 = 126$ $27 + 240 = 267$ $65 + 160 = 225$ $112 + 160 = 367$ $118 + 160 = 278$ $63 + 80 = 143$ $118 + 320 = 438$ $200 + 80 = 280$ $108 + 80 = 188$ $120 + 240 = 360$ $63 + 160 = 223$ $195 + 320 = 515$ $197 + 240 = 437$ $197 + 160 = 357$ $1 + 80 = 81$	Liquid bromine 79,450 99,050 120,600 78,200 76,200 69,000 63,000 26,000 { 101,400 (solid) 98,400(liquid) 24,500 23,700 64,900 34,800 42,400 12,100 1,000 8,400	207,500 93,200 77,200 59,000 118,000 52,200 8,400

^{1 8800} BERTHELOT.

HEAT OF FORMATION OF IODIDES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Zn, I ₂	65 + 254 = 319	49,200	60,600
Cd, I2	112 + 254 = 366	45,000	44,000
Pb, I ₂	207 + 254 = 461	42,000	
Cu, I ₂	63.5 + 254 = 317.5	16,500	
Hg, I ₂	200 + 254 = 454	14,200	
Ag, I (cryst.)	108 + 127 = 235	14,300	
Hg, I ₂ (red)	200 + 254 = 454	24,300	
3b, I ₃	120 + 381 = 501	29,200	
Au, I	197 + 127 = 324	-55,000	
H, I	1+127=128	- 6.400	13,200
K, I	46 + 127 = 173	87,500	
Na, I.	23 + 127 = 150	76,500	

CHEMICAL DATA

HEAT OF FORMATION OF CARBONATES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Ba, C, Os	137+12+48=197	286,300	
K ₂ , C, O ₈	78+12+48=138	282,100	288,600
Sr, C, O ₂	87+12+48=147	281,400	
Ca, C, O ₂	40+12+48=100	273,850	
Na ₂ , C, O ₃	46 + 12 + 48 = 106	273,700	279,300
Mg, C, O_8	24+12+48=84	269,900	
Mn, C, O ₈	55+12+48=115	210,300	
Z n, C, O ₈	65+12+48=125	197,500	
Fe, C, O	56+12+48=116	187,800	
Cd , C , O_2	112+12+48=172	183,200	
Pb, C, O ₂	207+12+48=267	170,000	• • • • • • • • • • • • • • • • • • • •
Cu, C, O3	63.6 + 12 + 48 = 123.6	146,100	• • • • • • • • • • • • •
Ag_2, C, O_3	216+12+48=276	123,800	
N, H ₄ H, CO ₈	14+4+1+12+48=79	205,300	199,000

HEAT OF FORMATION OF BICARBONATES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
K, H, C, O ₂	39+1+12+48=100 $23+1+12+48=84$	233,300	228,000
Na, H, C, O ₂		227,000	222,700

HEAT OF FORMATION OF SULPHATES

78+32+64=174 137+32+64=233 14+32+64=110 87+32+64=183 46+32+64=142 40+32+64=136 24+32+64=120 54+96+192=342 28+8+32+64=132 55+32+64=151 65+32+64=161	344,300 339,400 333,500 330,200 328,100 317,400 .300,900 283,500 249,400 229,600	337,700 339,600 321,800 321,100 879,700 281,100 263,200 248,000
14+32+64=110 87+32+64=183 46+32+64=142 40+32+64=136 24+32+64=120 54+96+192=342 28+8+32+64=132 55+32+64=151	333,500 330,200 328,100 317,400 .300,900 283,500 249,400	339,600 328,500 321,800 321,100 879,700 281,100 263,200
87+32+64=183 46+32+64=142 40+32+64=136 24+32+64=120 54+96+192=342 28+8+32+64=132 55+32+64=151	333,500 330,200 328,100 317,400 .300,900 283,500 249,400	339,600 328,500 321,800 321,100 879,700 281,100 263,200
87+32+64=183 46+32+64=142 40+32+64=136 24+32+64=120 54+96+192=342 28+8+32+64=132 55+32+64=151	330,200 328,100 317,400 ,300,900 283,500 249,400	328,500 321,800 321,100 879,700 281,100 263,200
46 + 32 + 64 = 142 $40 + 32 + 64 = 136$ $24 + 32 + 64 = 120$ $54 + 96 + 192 = 342$ $28 + 8 + 32 + 64 = 132$ $55 + 32 + 64 = 151$	328,100 317,400 .300,900 283,500 249,400	321,800 321,100 879,700 281,100 263,200
40 + 32 + 64 = 136 $24 + 32 + 64 = 120$ $54 + 96 + 192 = 342$ $28 + 8 + 32 + 64 = 132$ $55 + 32 + 64 = 151$	317,400 .300,900 283,500 249,400	321,800 321,100 879,700 281,100 263,200
24 + 32 + 64 = 120 $54 + 96 + 192 = 342$ $28 + 8 + 32 + 64 = 132$ $55 + 32 + 64 = 151$.300,900 283,500 249,400	321,100 879,700 281,100 263,200
54+96+192=342 28+8+32+64=132 55+32+64=151	283,500 249,400	879,700 281,100 263,200
28+8+32+64=132 $55+32+64=151$	283,500 249,400	281,100 263,200
55+32+64=151	249,400	263,200
		234,900
	i i	228,900
		228,700
$112 \pm 96 \pm 192 = 400$		650,500
	221.800	213,500
		231,600
		· ·
		210,200
		197,500
		162,600
		102,000
		281,100
		201,100
•	56+32+64=152 $59+32+64=155$ $58.5+32+64=154.5$ $112+96+192=400$ $408+32+64=504$ $112+32+64=208$ $207+32+64=303$ $2+32+64=98$	56+32+64=152 $59+32+64=155$ $58.5+32+64=154.5$ $112+96+192=400$ $408+32+64=504$ $112+32+64=208$ $207+32+64=303$ $2+32+64=98$ $63.6+32+64=159.6$ $400+32+64=159.6$ $400+32+64=496$ $216+32+64=312$ $200+32+64=296$ $9+32+64+126=281$ $8+8+32+64=132$ $171+32+64=267$ $344,700$

¹ 240,000 for FeSO₄ 7H₂O₋

HEAT OF FORMATION OF CHLORIDES

	AI OF TORMATION	OF CHEORIDE	
Formula	Molecular weights	Molecular heat of formation	In dilute solution
K, Cl. Ba, Cl ₂ . Be, Cl ₂ . Na, Cl.	$ \begin{array}{r} 39 + 35.5 = 74.5 \\ 137 + 71 = 208 \\ 9 + 71 = 80 \\ 23 + 35.5 = 58.5 \end{array} $	105,700 197,100 155,000 97,900	101,200 198,300 199,500 96,600
Li, Cl. Sr, Cl ₂ . Ca, Cl ₂ . N, H ₄ , Cl. Mg, Cl ₂ .	7 + 35.5 = 42.5 $87 + 71 = 158$ $40 + 71 = 111$ $14 + 4 + 35.5 = 53.5$ $24 + 71 = 95$	93,900 184,700 169,900 76,800 151,200	102,300 195,850 187,400 72,800 187,100
8, Cl ₂ . Al, Cl ₃ . Mn, Cl ₂ . Zn, Cl ₂ . Tl, Cl.	28+142 = 170 27+106.5 = 133.5 55+71 = 126 65+71 = 136 204+35.5 = 239.5	128,800 gas 161,800 112,000 97,400 48,600	238,100 128,000 113,000 38,400
Cd, Cl ₂ . Pb, Cl ₂ . Fe, Cl ₂ . Sn, Cl ₂ . Co, Cl ₂ .	112+71 = 183 207+71 = 278 56+71 = 127 118+71 = 189 59+71 = 130	93,700 83,900 82,200 80,900 76,700	96,400 77,900 100,100
Ni, Cl ₂ . Cu, Cl. Sn, Cl ₄ . Fe, Cl ₂ . Hg, Cl.	58.5 + 71 = 129.5 $63.5 + 35.5 = 99$ $118 + 142 = 260$ $56 + 106.5 = 162.5$ $200 + 35.5 = 235.5$	74,700 35,400 129,800 liquid 96,150 31,320	93,900
Sb, Cl ₂ . Bi, Cl ₂ . B, Cl ₂ . Ag, Cl.	120+106.5=226.5 $208+106.5=314.5$ $11+106.5=117.5$ $108+35.5=143.5$	91,400 90,800 89,100 gas 29,000 53,300	93,400
As, Cl ₂	63.6 + 71 = 134.6 75 + 106.5 = 181.5 1 + 35.5 = 36.5 120 + 177.5 = 297.5	51,400 71,500 22,000 104,500 liquid	62,500 39,400
Pd, Cl ₂ . Pt, Cl ₄ . Au, Cl ₂ . Au, Cl ₃ . P ₁ Cl ₃ .	106 + 71 = 177 $195 + 142 = 337$ $197 + 106.5 = 303.5$ $197 + 35.5 = 232.5$ $31 + 106.5 = 137.5$	40,500 60,200 22,800 5,800 69,700	79,800 27,200
Rb, Cl	85.5+ 35.4 = 120.9 133+ 35.4 = 168.4 91+ 32 = 123 140+ 32 = 172 28+141.7=169.7	105,900 109,900 177,500 224,600 121,800 gas	

HEAT OF FORMATION OF PHOSPHATES AND MISCELLANEOUS

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Mgs, P2, O2 Nas, P, O4	1+35.5+48=84.5 1+35.5+64=100.5 1+127+48=176	919,200 910,600 452,400	

¹ These results from "Annuaire du Bureau des Longitudes," 1914

HEAT OF FORMATION OF BI-SULPHATES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
K, H, S, O ₄	39+1+32+64=136 $23+1+32+64=120$ $14+5+32+64=115$ $1+1+32+64=98$	276,100	272,900
Na, H, S, O ₄		269,100	268,300
N, H ₅ , S, O ₄		244,600	245,100
H, H, S, O ₄		192,200	210,200

HEAT OF FORMATION OF SULPHITES

Formula	Molecular	Molecular heat	· In dilute
	weights	of formation	solution
S, O ₂ , K ₂	32+48+78=158	••••••	272,600
S, O ₂ , Na ₂	32+48+46=126		261,000

HEAT OF FORMATION OF NITRATES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
K, N, O ₈	39+14+48=101	119,000	110,700
Na, N, Os	23+14+48=85	110,700	106,000
Zn, N2, O6			131,700
Pb, N ₂ , O ₆		105,400	98,200
Cu, N ₂ , O ₆			81,300
H, N, O ₁	1+14+48=63	34,400 gas	48,800
Ag, N, Os		28,700	23,000
Ca , N_2 , O_6^1		202,000	• • • • • • • •
Co. Nr. Or 6HrO1	59 + 28 + 96 + 108 = 283		119,000
	7 + 14 + 48 = 69	112,000	
N. H., N. O.1	14 + 4 + 14 + 48 = 80	88,600	82,400

HEAT OF FORMATION OF ALUMINATES

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Ca, Al ₂ , O ₄ Ca ₂ , Al ₂ , O ₅ Ca ₂ , Al ₂ , O ₆	80+54+80=214	524,550 658,900 789,050	

HEAT OF FORMATION OF AMALGAMS

Formula	Molecular weights	Molecular heat of formation	In dilute solution
Hg12, K. Hg4, K. Hg6, Na. Hg2, Au. Hg2, Ag.	$\begin{vmatrix} 1,200 + 23 = 1,223 \\ x + 197 = 197 + x \end{vmatrix}$	34,600 29,700 21,900	25,600 25,600 19,000 2,580 2,470

302 METALLURGISTS AND CHEMISTS' HANDBOOK

HEAT OF FORMATION OF ALLOYS

Formula	Molecular weights	Molecular best of formation	In dilute solution
Cu, Zn: Cu, Zn Cuz, Al Cuz, Al Cuz, Al Cuz, Al Cuz, Al Cuz, Al Cuz, Alz Cuz, Alz Cuz, Alz Cuz, Alz Cuz, Alz Cuz, Alz Cuz, Alz	63 6+130=193.6 63.6+65=128.6 190.8+27=217.8 127.2+27=154.2 190.8+54=244.8 63.6+27=90.6 127.2+81=208.2 63.6+54=117.6	10,143 5,783 26,910 21,278 17,395 1,111 10,196 -6,738	

DEHYDRATION OF METALLIC SULPHATES

	-	METADEC SOUP	
	Temperature of beginning debydration, deg. C.	Product formed	Remarks
FeSO ₄ + 7H ₂ O. FeSO ₄ + 4H ₂ O. FeSO ₄ + 4H ₂ O. FeSO ₄ + H ₇ O. Al ₂ (SO ₄) ₄ + 16H ₂ O. Al ₂ (SO ₄) ₄ + 13H ₂ O. Al ₂ (SO ₄) ₄ + 10H ₂ O. Al ₂ (SO ₄) ₄ + 7H ₂ O. Al ₂ (SO ₄) ₄ + 4H ₂ O. Al ₂ (SO ₄) ₄ + 4H ₂ O. CuSO ₄ + 5H ₂ O. CuSO ₄ + 5H ₂ O. CuSO ₄ + H ₂ O. MuSO ₄ + 5H ₂ O.	21 80 406 51 82 97 109 180 216 27 93 155	FeSO ₄ + 4H ₂ O FeSO ₄ + H ₇ O FeSO ₄ + H ₇ O Fe ₂ O ₂ + 2SO ₃ Al ₂ ,SO ₄) ₂ + 13H ₇ O Al ₂ (SO ₄) ₃ + 10H ₇ O Al ₂ ,SO ₄) ₄ + 7H ₁ O Al ₂ (SO ₄) ₃ + 4H ₁ O Al ₂ (SO ₄) ₃ + 4H ₇ O Al ₂ (SO ₄) ₃ + H ₇ O CuSO ₄ + 3H ₇ O CuSO ₄ + H ₇ O CuSO ₄ MnSO ₄ + 2H ₇ O	White, Yellowish brown, White, White, White, White, White, Sky blue, Pale blue, White, Pale peach
Mn8O4 + 2HrO	60	MnSO4 + HsO	Paler than pre-
Mn804 + Hs0	152	Mn804	eeding. Paler than pre-
ZnSO ₄ + 7H ₂ O ZnSO ₄ + 6H ₂ O ZnSO ₄ + 2H ₂ O ZnSO ₄ + 1H ₂ O NiSO ₄ + 7H ₂ O NiSO ₄ + 4H ₂ O NiSO ₄ + 1H ₂ O CoSO ₄ + 7H ₂ O CoSO ₄ + 4H ₂ O CoSO ₄ + 4H ₂ O CdSO ₄ + 36H ₂ O CdSO ₄ + 2H ₂ O MgSO ₄ + 7H ₂ O MgSO ₄ + 6H ₂ O MgSO ₄ + 6H ₂ O MgSO ₄ + 2H ₂ O CaSO ₄ + 2H ₂ O CaSO ₄ + 2H ₂ O ZCaSO ₄ + 2H ₂ O 2CaSO ₄ + 1H ₂ O	25 28 115 225 40 106 279 19 58 276 30 41 170 19 38 112 203 80 80 149	ZnSO ₄ + 6H ₂ O. ZnSO ₄ + 2H ₂ O. ZnSO ₄ + H ₂ O. ZnSO ₄ + H ₂ O. NiSO ₄ + 4H ₂ O. NiSO ₄ + H ₂ O. CoSO ₄ + 4H ₂ O. CoSO ₄ + H ₂ O. CoSO ₄ + H ₂ O. CdSO ₄ + H ₂ O. CdSO ₄ + H ₂ O. CdSO ₄ + H ₂ O. MgSO ₄ + 6H ₁ O. MgSO ₄ + 2H ₂ O. MgSO ₄ + H ₂ O. CaSO ₄ + H ₂ O. CaSO ₄ + H ₂ O.	ceding. White, White, granular. White, White. Green. Yellow. Orange colored, Rose. Lilac. Lilac, White. White. White.

HEAT OF FORMATION OF HYDROCARBONS (All formed in state of gas, unless otherwise specified)

	(All form	ed in state of gas, un	(All formed in state of gas, unless otherwise specified)	(
·		-1-74	1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -	Molecular	Heat of co	Heat of combustion
Name	Formula	Moights Weights	Molecular near of formation	plete com- bustion	1 m. ² (cal.)	1 ft.3 B.t.u.
Methane (marsh gas)	(C,H4)	12 + 4 = 16	22,250	191,070	8,598	996
enny vene)	(C ₂ , H ₄)	24 + 6 = 30	26,650	341,930	15,387	1,728
hydride)h	(C, H,	∭ ∞	33,850	489,900	22,050	2,477
Ethylene (olefiant gas).	(C,H,)	+ 4=	$ -11,\!250$	321,770	14,480	1,627
Propylene	(Cs, He)	# 0 + ·		471,830	21,232	2,385
Toluene	(1) H	84+8= 92 72+6= 78	5,650 (liquid)	906,990 758,130	•	•
		•		765,330	34,440	3.869
Turpentine	(C10, H16)	120 + 16 = 136		1,428,930		
Nonhthalina	(C. H.)	120 T S=128	$\begin{bmatrix} -1,850 & (gas) \\ -10.450 & (solid) \end{bmatrix}$	1,438,330	64,725	7,271
Tapmamamamamamamamamamamamamamamamamamam	(610)	071-0-1071	-24.050 (liquid)	1.228,290	55.273	6.209
Anthracene	(C14, H10)	168+10=178		1,690,150		• • • • • • • • • • • • • • • • • • • •
:	(C ₂ , H ₃)	24 + 2 = 26	-54,750	365,270	16,437	1,846
spirit)	(C, H, O)	12 + 4 + 16 = 32	65,050 (liquid)	148,270	•	•
T+hailelachal (clackal)	(C, H, O)	91 LA L16 - 18	56,650 (gas)	156,670	7,050	199
Living 1-arconol (arconol)	(02, 116, 0)	_	ごご	305,430	13,744	1,544
Acetone	(C, H, 0)	36+6+16=58	69,650 (liquid) 62,150 (gas)	396,130 403.630	18.163	2.040
				, , , , , , , , , , , , , , , , , , , ,		

HEAT OF SOLUTION

Salt dissolved	Calories
$CuSO_4.5H_2O$	2,750
$CdSO_4.8\%H_2O$	
$ZnSO_4.7H_2O$	4,260
$FeSO_4.7H_2O$	
ZnCl ₂ in water	
ZnSO ₄ in water	

DESULPHATIZATION OF ANHYDROUS METALLIC SULPHATES¹

Metallic sulphates	Temperature of beginning of decomposition, deg. C.	Temperature of energetic decomposition, deg. C.	Products of decomposition	Remarks
Fe ₂ (SO ₄) ₃ . Fe ₂ O ₃ .2SO ₃ Bi ₂ (SO ₄) ₃ . Al ₂ (SO ₄) ₃ . PbSO ₄ . CuSO ₄ . MnSO ₄ . ZnSO ₄ . 2CuO·SO ₃ . NiSO ₄ . CoSO ₄ . 3ZnO·2SO ₃ . CdSO ₄ . 5Bi ₂ O ₃ ·4(SO ₃) ₃ . 5CdO·SO ₃ . MgSO ₄ . Ag ₂ SO ₄ . 6PbO·5SO ₃ . CaSO ₄ .	492 570 590 637 653 699 702 702 702 720 755 827 870 878 890 917	480 560 639 639 705 670 790 720 736 764 770 767 846 890 890 972 925 962	Fe ₂ O ₃ .2SO ₃ . Fe ₂ O ₄ . Fe ₂ O ₄ . 5Bi ₂ O ₄ ·4(SO ₃) ₃ . Al ₂ O ₃ . 6PbO·5SO ₂ . 2CuO·SO ₃ . Mn ₃ O ₄ . 3ZnO·2SO ₃ . CuO. NiO. CoO. ZnO. 5CdO·SO ₃ . Bi ₂ O ₃ (?). CdO. MgO. Ag. 2PbO·SO ₃ (?) CaO. BaO.	White. White. White. Orange color. Dark red to black. White, cold and hot. Black. Brownish green. Brown to black. Hot yellow, cold white. White. Yellow. Black. White. Silver white. White to yellow.

Dissociation Tensions of Sulphates at Various Temperatures. Expressed in Millimeters of Mercury

Temp., deg. C.	Fe ₂ (SO ₄) ₃	CuSO ₄	Al ₂ (SO ₄) ₈	2CuO·SOs	ZnSO ₄
550	9.8	25.5	9.8	1	
600	22.8	28.7	16.0	27.6	
650	58.0	37.7	25.8	33.0	
675	94.0	50.5	34.0		0.5
700	219.0	71.0	50.0	36.0	0.8
72 5		148.0	82.0	39.0	l
750 ·	1			46.0	7.5
775					14.5
800				85.0	24.0

¹ Hofman, "General Metallurgy." For additional data on decomposition see pp. 305, 523 and 524.

Reduction Temperatures of Metallic Oxides

Various metallic oxides were submitted to the action of hydrogen, carbon monoxide, ammonia and methane, at various temperatures for a period of 6 hours, and the investigators report in the *Journ. Soc. Chem. Ind.*, July 30, 1910, the lowest temperatures at which the oxides begin to lose oxygen. The accompanying tabulation shows the results obtained.

TEMPERATURES AT WHICH OXIDES OF THE METALS GIVE UP OXYGEN

Oxide	Carbon monoxide, 'deg. C.	Hydrogen, deg. C.	Ammonia, deg. C.	Methane, deg. C.
Au ₂ O ₂ Ag ₂ O Hg ₂ O HgO (yellow). HgO (red) Pb ₂ O Pb ₂ O ₂ Pb ₃ O ₄ PbO CuO Cu ₂ O ZnO As ₂ O ₃	0 and below 0 0 and below 90 110 150 160 75 140 170 60	0 and below 0 80 50 115 150 170 190 125	67 157 202 198 Above 300 299 225 208	l .

Reduction Temperatures of Some Refractory Oxides¹

Oxide and carbon	Reduction tempera- ture	Remarks
BeO	2400°	Forms carbide.
MgO		Oxide dissociates before reduction.
CaO	1540°	Carbide dissociates above 800°.
Al ₂ O ₈	1800°	Forms carbide.
B_2O_3	2400°	Carbide sublimes.
\mathbf{MnO}	1100°	Carbide dissociates at 1550°.
UO_2	1600°	Forms carbide.

Reduction by Hydrogen

A paper on "The Reduction of Metallic Oxides with Hydrogen at High Pressures," by E. Newbery and J. N. Pring, was read at a meeting of the Royal Society, January, 1916. Metallic oxides have been heated to temperatures of 2500°C. in dry hydrogen at pressures up to 150 atmospheres, water vapour being removed by metallic sodium. The following oxides were reduced to metals: Cr_2O_3 to Cr and MnO_2 to Mn. The following oxides were reduced to lower oxides: V_2O_5 to VO, Nb_2O_5 to NbO, U_3O_8 to UO_2 , TiO_2 to TiO, and CeO_2 to Ce_2O_3 . The following oxides were unchanged: Al_2O_3 , MgO, ZrO_2 , Y_2O_3 , ThO_2 . The metals obtained, chromium and manganese, are

¹ Zeit. für angew. Chemie., p. 118, Vol. XXVIII, 1915.

probably the purest samples of these metals that have been prepared up to the present. This supposition is supported by the sharp nature of their melting points, a feature which has not been observed with samples prepared by other methods.

Decomposition of Carbonates¹

$ZnCO_3 = ZnO + CO_2 \dots \dots$	30000
$2nOO_3 = 2nO + OO_2 \dots \dots$.000 0.
$MgCO_3 = MgO + CO_2 \dots$.650°C.
FeCO ₃ = No simple product	.800°C.
$CaCO_3 = CaO + CO_2 \dots$.812°C.
$SrCO_3 = SrO + CO_2 \dots begins 1$	
$BaCO_3 = BaO_1 + CO_2 \dots begins$	
$MgCO_3 = MgO + CO_2 \dots$.546°C.
Decomposition of Sulphides ²	
Pyrite $- \text{FeS}_2 = \text{FeS} + \text{S}$. 565°C.
Chalcopyrite	

Oxidation of Metallic Oxides at High Temperatures and Pressures

J. MILBAUER has experimented on the reactions of metallic oxides at high temperatures and pressures (Journ. Soc. Chem. Ind., May 31, 1916). When heated in oxygen for an hour at 480°C., and 12 atmospheric pressure, most of the normal metallic oxides remained unchanged. The following exceptions were noted: Potassium and barium oxides were converted into peroxides, lead oxide into red lead, antimony oxide into the tetroxide, and manganese oxide into sesquioxide; the lower oxides of nickel and cobalt yielded traces of nickelic and cobaltic oxides. Silver was converted into black crusts of, apparently, a peroxide, since on treatment with hydrochloric acid they yielded chlorine. Platinum remained unchanged. Experiments under similar conditions with metallic oxides intimately mixed with chromium sesquioxide, showed in many cases a more or less complete conversion into metallic chromate with absorption of oxygen. Thus, for example, the products obtained from chromium oxide and the following oxides (or carbonates) contained the annexed percentages of chromate respectively: Silver oxide, 100 per cent. of chromate; magnesium oxide, 82.7 per cent.; calcium oxide, 56.9 per cent.; zinc oxide, 72 per cent.; and lead carbonate, 100 per cent. The reaction is therefore available for the preparation of certain chromates, notably that of magnesium, which in many cases can be substituted for alkali chromates.

¹ See pp. 523 and 524 for additional data.

Molecular Heat of Dilution¹

The heat set free or absorbed on diluting a gram molecule of liquid with water is the molecular heat of dilution, thus on diluting HCl to (HCl, 300 H₂O) 17,300 cal. per 36.5 grams of HCl are set free; diluting 2NaCl, nH₂O (n = 20) to (2NaCl, 100 H₂O) absorbs 1060 cal. per 2 × 58.65 grams of NaCl.

	Cl 0 H ₂ O		NO: 0 H ₂ O		28O ₄ 0 H ₂ O		aOH 3 H ₂ O	N	Ha ² n
1 2 5 50 300	5,370 11,360 14,960 17,100 17,300	1 5 10 20 320	3,280 6,600 7,320 7,460 7,490	1 5 49 199 1,600	6,380 13,100 16,700 17,100 17,900	5 7 9 25 200	2,130 2,900 3,100 3,260 2,940	1 3 5.8 9.5 110	1,260 385 210 20
	aCl 0 H ₂ O		BNO: 12 H ₂ O		a ₂ SO ₄ 50 H ₂ O		nCl ₂ 5 H ₂ O		NO:): = 10
200	-1,060 -1,310 -1,410	100 - 200 -	-2,260 -3,290 -3,860 -4,190	200 400	0 - 665 0 -1,130 0 -1,380 0 -1,480	10 20 50 100 400	1,850 3,150 5,320 6,810 8,020	15 20 50 100 200	910 1,150 1,200 1,100 1,070

STANDARDS FOR WORK WITH THE BOMB CALORIMETER³

	Berthelot	Atwater	Fischer & Wrede	U. S. Bureau of Standards	
Naphthalene Benzoic acid Cane sugar (sucrose).	9692 6322 3961	9628 6322 3957	9640 6333 3957	9610 6320	

¹ From Kaye and Laby, Physical and Chemical Constants.''

² Heat developed on diluting NH₂·nH₂O to NH₂·200H₂O (BERTHELOT).

³ From Somermeier's "Coal."

Thermoelectric Constants

The electromotive forces¹ given by various thermo-couples in general use, and at a temperature of 500°C., with the cold junction temperature 0°C., are as follows:

-	Approximate electro- motive force in milli- volts at 500°C.
Platinum-platinum 10 per cent. rhodium	4.4
Platinum-platinum 10 per cent. iridium	7.4
Nickel-nickel 10 per cent. chromium (The Hoskin's	
couple)	10.0
Iron-nickel	12.0
Iron-constantan	26.7
Silver-constantan	27.6
Copper-constantan	. 27.8

The relation between temperature and the electromotive force produced by a thermo-couple when the cold junction is maintained at 0°C. is usually given in an equation of the form

$$\log e = A \log t + B,$$

where

e = e.m.f. of the thermo-couple in millivolts,

t = the temperature of the thermo-couple in degrees Centigrade,

and A and B are constants depending on the wire employed.

For the chief thermo-couples in general use at the present time this equation is as follows:

	$\log e = 1.19$	
Platinum-platinum iridium approximately	$\log e = 1.10$	$\log t + 0.89$
Silver-constantan approximately	$\log e = 1.14$	$\log t + 1.34$

(See also p. 171)

¹ Engineering, Aug. 1, 1913.

THERMOCHEMICAL CONSTANTS PER CHEMICAL EQUIVALENT WITH CORRESPONDING VOLTAGES

In the table of thermo-chemical constants per chemical equivalents (by J. W. Richards, Journ. Franklin Inst., 1906) the column headed "per chemical equivalents" gives the additional energy in case of the plus figures, or the smaller amount, in case of the negative, required to set free a chemical equivalent (molecular weight divided by valence) of the given substance as compared with the energy required to decompose the corresponding hydrogen compound.

In the formation of CuCl₂ the data in the table are -7900 Cu, +39,400 Cl₂ = 31,500 gram-cal. required for the decomposition of one chemical equivalent of CuCl₂, the corresponding drop in voltage is -0.34 Cu, +1.71 Cl₂ = 1.37 volts for the decomposition voltage of CuCl₂. The order in which the elements are placed gives also the order in which they will be

deposited one after another by decreasing voltages.

	Basic element	•		Acid e	emente	
Element	Per chemical equivalents, gram-cals.	Corre- sponding voltage	Element	Per chem. equiv., gram-cal.	Corre- sponding voltage	Salt
Li' Rb' K' Ba" Na' Na' Na' Al" NH' Zn" Cd" Co" Ni" Fe" Cd" Hg" Hg" Ag"	+62,900 +62,000 +61,900 +59,950 +58,700 +57,200 +54,400 +54,300 +40,100 +33,400 +17,200 +17,200 +19,900 +8,200 +7,700 +3,230 +1,900 +400 -7,900 -7,900 -14,250 -19,450 -25,200 -30,300	+2.73 +2.69 +2.60 +2.55 +2.36 +2.36 +2.36 +2.36 +2.36 +2.36 +1.08 +0.33 +0.33 +0.33 +0.08 +0.02 -0.04	F:" (gas) Cl2" (gas) Br1" (gas) Br' liquid) It" (gas) It (liquid) It (solid) Se" (met.)	+52,900 +39,400 +32,300 +28,600 +27,300 +20,000 +14,600 +13,200 -5,100 -17,900	+1.71 +1.40 +1.20 +1.18 +0.87 +0.57 -0.22	Fluoride, Chloride, Bromide, Bromide, Iodide, Iodide, Iodide, Sulphide, Selenide,

Calculation of Electromotive Force (Thomson's Rule)

One coulomb liberates 0.000010392 grams of H. In order to set free 1 gram of H, or 1 gram equivalent of any other element, an expenditure of $1 \div 0.000010392 = 96,600$ coulombs is required. This is known as a Faraday and is usually denoted by the letter F.

If Q is the heat energy of formation of one molecular weight, n the valence of the compound, then

or since

$$nEF = Q \times 4.19$$
 $F = 96,600$
 $E = \frac{Q}{23,040n}$ (Thomson's rule).

The rule is not quite correct. The true relation between heat and electrical energy is given by the GIBBS-HELMHOLZ equation

$$nEF = Q + T \frac{dE}{dT}$$

in which T = absolute temperature, and $\frac{dE}{dT}$ is the temperature coefficient of the e.m.f. As this coefficient is usually not large, Thomson's rule is sometimes used to give an approximate value.

Example:

Cu + Cl₂ +
$$aq = 62,500$$
; $n = 2$ valences
$$E = \frac{62,500}{23,040 \times 2} = 1.36 \text{ volts}$$
CuSO₄ + H₂O = Cu + H₂SO₄ + O
197,500 + 69,000 - 210,000 = 56,300
$$E = \frac{56,300}{2 \times 23,040} = 1.22 \text{ volts}$$

Electroplating Baths¹

Brass Bath (Roseleur's).—Per liter of water:	
Sodium carbonate, dry (Na ₂ CO ₃)	10 g.
Cupric acetate, pulverized	14 g.
Sodium bisulphite (HNaSO ₃)	14 g.
Zinc chloride, fused (ZnCl ₂)	14 g.
Potassium cyanide (100 per cent. KCN)	40 g.
Ammonium chloride (NH ₄ Cl)	2 g.

Current density, 0.3 amp. per sq. dm.; e.m.f., 2.7 volts; sp. gr., 1.0545; deposit per hour, 0.0041 mm.

Dissolve the sodium salts in 400 cc. warm water, stir the copper and zinc salts with 400 cc. of warm water, and stir slowly into the first solution. Dissolve the cyanide in the remainder of the water and stir into the other portion of the bath, where the precipitate should dissolve. Add the ammonium ablarida and bail for an all stir into the other portion of the nium chloride and boil for an hour, replacing the water evaporated.

Copper Bath—Acid.—Per liter of water:	
Copper Bath—Acid.—Per liter of water: Copper sulphate (CuSO ₄ ·5H ₂ O)200	g.
Sulphuric acid (conc. H ₂ SO ₄)	g.
Current density, 1 to 3 amp. per sq. dm.; sp. gr. 1.1417.	_
1 "A Laboratory Course in Electrochemistry," WATTS.	

Nickeling on Zinc.—Per liter of water:
Nickel sulphate
Sodium citrate
Current density, 0.27 amp. per sq. dm.; e.m.f., 3.6 volts; sp.
gr., 1.0394; deposit per hour, 0.00301 mm.; rolled anodes should have two and one-half times area of cathodes.
Nickel Solution—Thick Deposits.—Per liter of water:
Nickel sulphate, NiSO ₄ ·7H ₂ O
Ammonium tartrate, neutral
Current density, 0.3 amp. per sq. dm.
Black Nickel.—Per liter of water:
Nickel-ammonium sulphate
Use nickel anodes three to four times the surface of the
cathodes. Current density, 0.05 amp. per sq. dm. Deposit
takes best on white nickel. Solution must be kept neutral by nickel carbonate.
Platinum Bath—(Roseleur's).—Per liter of water:
Thin Thick
deposits deposits Ammonium phosphate 20.0 g. 100.0 g.
Sodium phosphate
Platinum as $PtCl_4$
Current density, 1 to 2 amp. per sq. dm.; e.m.f., 3 to 4 volts. Dissolve the platinic chloride in 100 cc. of water. Dissolve
the ammonium phosphate in 200 cc. of water and stir into the
platinum solution, when the precipitate previously formed will
dissolve. Boil until odor of ammonia has disappeared and add
water to make up for evaporation. Bath should have acid reaction and should be used hot. Potential difference, 6-8
volts.
Silver Bath—Heavy Plating.—Per liter of water:
Silver as silver cyanide
Current density, 0.3 amp.; e.m.f., 1.3 volts; sp. gr., 1.0338;
deposit per hour, 0.0114 mm.; area of anodes equals area of cathode.
Silver Bath—Ordinary Plating.—
Silver as silver cyanide
Current density, 0.3 amp. per sq. dm.; e.m.f., 1.5 volts; sp. gr.,
1.0175; deposit per hour, 0.0115 mm.
Tin Bath (Roseleur's).—Per liter of water:
Sodium pyrophosphate (Na ₄ P ₂ O ₇)
Tin chloride, fused (SnCl ₂)

Current density, 0.3 amp. per sq. dm.; e.m.f., 2 volts; sp. gr., 1.0357; deposit per hour, 0.0059 mm.; anode area equal to cathode, solution gives deposit on copper, brass, bronze or zinc; but iron or steel must be coppered first or given a preliminary coat of tin by an immersion bath. The tin anodes do not corrode evenly and tin salts must be added to maintain sufficient amount of tin in solution.

Tin Baths.—Per liter of water:

į daras ir salas ir s		а	b	с
Caustic soda	$\begin{array}{c} (\operatorname{SnCl_2} \cdot 2\operatorname{H_2O}) \\ (\operatorname{Na_2S_2O_3} \cdot 5\operatorname{H_2O}) \end{array}$	30 g.	120 g. 30 g. 60 g.	50 g.

Tin Bath, by Immersion.—Per liter of water:

Ammonium alum (NH₄Al(SO₄)₂·12H₂O) 25 g. Tin chloride, fused (SnCl₂)...... 2 g.

A bright coating is produced on clean iron by 30 to 60 seconds immersion in the boiling solution.

Zinc Bath.—Per liter of water:

Ammonium citrate...... 40 g.

Current density, 0.5 to 1.0 amp. per sq. dm.; e.m.f., 1.1 to 2.2; sp. gr., 1.0781; deposit per ampere-hour, 0.0173 mm.

Zinc Bath.—Per liter of water:

Hydrochloric acid..... Glycerine..... 4 g.

Use anodes of zinc and of antimonial lead in equal numbers.

Electrolytic Oxidation and Reduction

Overvoltage of Hydrogen and Oxygen. (Quoted from Watts "A Laboratory Course in Electrochem-

istry.")

"Electrolysis lends itself well to oxidation and reduction processes, since it is possible to vary not only the speed, but also the intensity of the action with great nicety. Factors affecting the intensity of the reducing action are the material of the electrode, the nature of its surface, and the current density. In comparing the effects of different cathodes, an attempt is frequently made to resolve the reducing action of the cathodes into the catalytic action of the electrode material, and the 'overvoltage' of the

OVERVOLTAGE OF HYDROGEN

_				,			
	Cas- Pigne		erater and 2 N-HaSO4	2N H ₂ 80 ₄ 0.125	By Tafel*	Discharge poten- tials, N.HsSO ₄	
Cathode	parit N H= 804	Least poten- tial	Current 0 04 amp. per sq. cm	amp. per aq. cm.	0.1 amp.	From Caspari	From Foer- ster
Mercury Zinc Lead, Tin. Cadmium Palladium Copper Nickel Silver Platinum Gold. Platinised- platinum.	0.78 0.70 0.64 0.53 0.48 0.46 0.23 0.21 0.15 0.09 0.02	0.43 0.35 0.43 0.48 0.10 0.10 0.07 0.055 0.005	1 25 1 26 1 08 1 18 0 67 0 64	1.33 1.35 1.16 1.23 0.79 0.74	1.30 1.30 1.15 1.22 0.79 0.74 0.93(?) 0.95	+ 5476 + 4676 + 4076 + 2976 + 2476 + 2276 - 0024 - 0224 - 0824 - 1424 - 2124 - 2324	+ .1976 + .1676 + .1676 + .1976 1324 1334 1624 1874 2274

NOTE.—" N" in the above table stands for normal.

¹ Zeit. phys. Chem., 1899, p. 89. ² Zeit f. Elektrochem, 1904, p. 715. ³ Zeit. f. Chem., 1904, p. 712.

hydrogen. The variation in the potential required by elec-trodes of different metals for visible evolution of hydrogen is usually expressed as the "overvoltage" of hydrogen on the particular metal, the least potential of platinized platinum being taken as zero. The discharge potentials referred to the calomel electrode (value, -0.56 volt) have been calculated for the difference between the calomel electrode and the hydrogen electrode in normal sulphuric acid. The increase of overvoltage with time and its diminution with rise of temperature varies for different metals.

Anode Potentials and Overvoltage of Oxygen

Anode	By Coebn. Least anode potential for evolution of Or ve hyd. electrode in N KOH	Overvoltage All- mand, p. 181	Discharge potential vs. calonel electrods calculated by Watte	By Foerster. Least potential for evolution hyd vs. hyd. electrode	2N KOH after 2 bours, 15°C,	2N KOH 98°C.	2N H,804-99°C.
Nickel, sponge. Nickel, smooth. Cobalt. Iron Platinised- platinum Copper Lead. Silver Cadmium Palladium Platinum	1.28 1.35 1.36 1.47 1.48 1.53 1.65 1.65 1.67 1.75	0.05 0.12 0.13 0.24 0.25 0.30 0.40 0.42 0.42 0.42 0.42	-0.9524 -1.0224 -1.0324 -1.1424 -1.1424 -1.1524 -1 2024 -1 3024 -1 3224 -1 3224 -1 3424 -1 4224	1.35 1.47 1.47	2.00 2.02 2.30 2.45 2.92	1.77 1.89 2.50	2.17

Electrochemical Order of the Elements¹

In the following series each metal is electropositive to all that follow it. Two metals in contact in the presence of an electrolyte form a galvanic couple which causes the more electropositive to be decomposed by electrolysis.

Cs+, Rb, K, Na, Li, Ba, Sr, Ca, Mg, Al, Cr, Mn, Zn, Ga, Fe, Co, Ni, Tl, In, Pb, Cd, Sn, Bi, Cu, H, Hg, Ag, Sb, Te, Pd, Au, Ir, Rh, Pt, Os, Si, C, B, N, As, Se, P, S, I, Br, Cl, O, F.

Some authors put Cd just before Fe, Sn before Pb, and Sb and As before Cu. That the last two should precede copper ordinarily seems probable. The order changes with the specific electrolyte, and the position of selenium varies with the amount of illumination.

POTENTIALS OF METALS IN THEIR NORMAL SALTS (NEUMANN)

	Sulphate	Chloride	Nitrate	Acetate
Magnesium	+1.239	+1.231	+1.060	+1.240
Aluminum	+1.040	+1.015	+0.775	
Manganese	+0.815	+0.824	+0.560	
Zinc	+0.524	+0.503	+0.473	+0.522
Cadmium	+0.162	+0.174	+0.122	••••••
ron	+0.093	+0.087	0.070	
obalt	-0.019	-0.015	-0.078	-0.004
lickel	-0.022	-0.020	-0.060	•••••
	• • • • • • • • • • • •		-0.115	0.070
ead	-0.238	-0.095 -0.249]	$ \begin{array}{c c} -0.079 \\ -0.150 \end{array} $
Bismuth	-0.238 -0.490	-0.245 -0.315	-0.500	-0.130
Intimony		1 1 1 1	-0.000	
rsenic				
Copper	-0.515			-0.580
Mercury	-0.980		1	
ilver	-0.974		4 0 2 2	-0.991
Palladium	• • • • • • • • • • • •	-1.066		
Platinum		-1.140		
	• • • • • • • • • • • •	-1.356		

DECOMPOSITION VOLTAGES (LE BLANC)

H ₂ SO ₄ 1. HNO ₃ 1. H ₂ PO ₄ 1. HCl 1. NaOH 1. KOH 1. NH ₄ OH 1. Na ₂ SO ₄ 2. NaNO ₃ 2. NaCl 1. NaBr 1.	69 NaC ₂ H ₂ O ₂ 70 K ₂ SO ₄	2.10 2.20 2.17 1.96 2.11 1.89 2.01 1.95 2.35	NiSO ₄ NiCl ₂ AgNO ₃ CdSO ₄ CoSO ₄ HgCl ₂ Fe ₂ (SO ₄) ₃ FeSO ₄ AuCl ₂ FeCl ₂	1.84 0.70 2.03 1.92 1.30 1.64 2.02 0.39	SnCl ₂ MnSO ₄ . MnCl ₂ CuCl ₂	1.76 2.60 2.77 1.36
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¹ GORE, "The Art of Electrolytic Separation of Metals."

ELECTROMOTIVE FORCE OF METALS AND MINERALS IN KCN Solution¹

 $\frac{M}{1}$ KCN = 6.5 per cent.

	Volts		Volts
Aluminum. Zinc, amalgamated. Copper. Cadmium. Tin. Bornite. Copper, amalgamated. Gold. Silver. Copper glance. Lead. Quicksilver Gold, amalgamated. Antimony Arsenic. Bismuth. Niccolite.	+0.99 +0.93 +0.81 +0.61 +0.45 +0.39(?) +0.37 +0.33 +0.29(?) +0.13 -0.09 	Iron. Chalcopyrite. Pyrite. Galena. Argentite. Speiss (cobalt). Arsenopyrite. Platinum. Cuprite. Electric-light carbon. Blende. Bournonite. Coke. Ruby silver ore. Stephanite. Stibnite.	-0.17 -0.20 -0.28 -0.28 -0.30 -0.40 -0.43 -0.46 -0.48 -0.50 -0.52 -0.54 -0.54

DECOMPOSITION VOLTAGES OF MOLTEN ALKALI HALIDES AND ALKALINE-EARTH CHLORIDES²

Compound	Decompound voltage	Temp. coeff.
LiCl. NaCl. KCl. NaBr. KBr. NaI. KI. Na ₂ SO ₄ . K ₂ SO ₄ . Na ₂ CO ₃ . CaCl ₂ . SrCl ₂ . BaCl ₂ .	630° C. = 2.62 v. 835° C. = 2.6 v. 810° C. = 2.8 v. 690° C. = 2.45 v. 690° C. = 2.6 v. 630° C. = 2.05 v. 630° C. = 2.2 v. 890° C. = 2.5 v. 890° C. = 2.6 v. 770° C. = 1.3 v. 585° C. = 2.85 v. 615° C. = 3.0 v. 650° C. = 3.05 v.	1.35×10^{-3} 1.46×10^{-3} 1.51×10^{-3} 1.465×10^{-3} 1.465×10^{-3} 1.48×10^{-3} 1.48×10^{-3} 2.00×10^{-3} 2.00×10^{-3} 0.685×10^{-3} 0.715×10^{-3}

¹ Prof. S. B. Christy, *Trans.* A. I. M. E., Sept., 1899.

² B. Neumann and E. Bergve. *Z. Elektrochem.* 21, 152–60 (1915).—For these experiments a C crucible covered with a mixture of water-glass and asbestos was found to be the only one practicable. Graphite electrodes were used covered, where exposed, with the same mixture.

Deposition by Immersion¹

Solution	Deposits on	Does not deposit on
	Bi, Brass, German Ag, Pb, Sn, Zn	
	Fe, Pb, Sn, Zn	
$CuSO_4$, $Cu-(NO_2)_2$	Fe, Pb, Sn, Zn	Sb, Bi, Cu, Au, Ni, Pt.
CuCl ₂	Bi, Fe, Pb, Sn, Zn	Sb, Cu, Au, Ni, Pt, Ag.
CuCl ₂ (am-	_	
moniacal).	Zn	Sb, Cu, Au, Bi, Fe, Pb, Ni, Pt, Ag.
HgNO	As, Bi, Cd, Cu, Sb, Fe,	, , , , ,
	brass, Pb, Zn	
AgNo ₂	Pb, Sn, Cd, Zn, Cu, Bi,	
_	Sb, Fe, Ni	Ag, Au, Pt.
AgNo ₂	As, Sb, Bi, Zn, Sn, Cu,	Fe.
(alcoholic).		4
AgCN·KCN	Zn, Pb, Cu, brass,	Sb, Bi, Sn, Fe, Ni,
_	German Ag.	Ag, Au, Pt.
Au(CN).KCN		Sb, Bi, Sn, Pb, Fe,
(/	Ag.	Ni, Ag, Au, Pt.
	·-b·	(111, 115, 11u, 1 u.

Cleaning Metals by Electrolysis.—In cleaning adhesions of dirt, rust, etc., from metals, the following method is recommended: The articles are connected to the poles of an alternating circuit and immersed in a salt solution. The liberation of gases on the surface of the metals very quickly removes or loosens everything of a non-metallic character, while the alternating current prevents any permanent action on the metal itself, and it is said the finish of the surface is not interfered with. The voltage should be sufficient to cause evolution of gas at the poles, and currents up to 110 volts have been used. (Mining Review, Melbourne, Aust.)

Other authorities recommend a 10 per cent. solution of H₂PO₄. A carbon electrode is used if both electrodes cannot

be composed of metals to be cleaned.

A mixture of freshly moistened crushed sodium bisulphate and common salt can also be used. This is applied and allowed to remain in contact with the plate to be cleaned for some time. After the plate is clean the mixture should be scraped off and the plate washed with an alkaline solution.

¹ Gore, "Art of Electrolptic Separation of the Metals."

SECTION V

SAMPLING, ASSAYING AND ANALYSIS¹

STANDARD SOLUTIONS

Ammonium-nitrate solution—for washing ammonium phosphomolybdate—5 to 10 per cent. Dissolve 50 to 100 grams NH₄NO₂ in water and acidify with HNO₃, using 1 cc. per liter excess. Or add ammonia to strong HNO₃ (sp. gr. 1.42) until alkaline to litmus, and bring back to acidity with HNO₃, using 1 cc. per liter excess.

Ammonium-oxalate solution—used chiefly as a precipitant for calcium. 1 gram of salt per 10 cc. of water. 1 cc. will

then precipitate 0.0145 gram of CaO.

Barium chloride—used as precipitant for SO₃. 1 gram of crystals per 10 cc. of water. 1 cc. will precipitate 0.0327 gram SO₃.

Bichromate solution—for iron determination—8.79 grams pure K₂Cr₂O₇ in two liters of water. 1.0 cc. = 0.005 mg. Fe.

Cochineal—Grind 1 gram of the bugs in a mortar and digest with 100 to 150 cc. of cold dilute alcohol (1 vol. alcohol, 3 vol. water) for 20 or 30 min. Filter and the solution is ready for use. See note under phenolphthalein concerning acidity of alcohol. Useful with titrations with ammonia. Salts of copper, iron and aluminum must be removed. Color changes

from yellowish red in acids to purple in alkalis.

Cuprous-chloride solution (ammoniacal)—for gas analysis. Weigh out 16 grams of fresh Cu₂Cl₂, or about 25 if it is old. Place in large Florence flask and add 250 cc. water. By means of delivery tube immersed in water, pass the gas from 200 cc. concentrated ammonia water into the Cu₂Cl₂ flask using a two-hole stopper in this flask with a check valve. Pass until practically all ammonia has passed over. 100 cc. of this Cu₂Cl₂ solution will absorb 24 cc. of CO but should not be used in second pipette after it has absorbed 6.

Cyanide solution—for copper determination. Use about 23 grams commercial potassium cyanide per liter of water. The

theoretical amount is 20.63. 1.0 cc. = 0.005 gram Cu.

Ferrocyanide—for zinc determination—45 grams of pure

 K_4 FeCy₆ per liter of water. 1.0 cc. = 0.010 gram Zn.

Hydrodisodium phosphate—HNa₂PO₄—used as precipitant for magnesia. 1 gram to 10 cc. of water. 1 cc. of solution precipitates 0.0112 gram of MgO.

Hyposulphite solution—for use in iodide copper determination—19.59 grams c.p. sodium hyposulphite per liter of water.

1.0 cc. = 0.005 g. Cu.

Litmus—Dissolve 1 gram of litmus in 100 cc. of hot water

¹ For data on qualitative analysis see the previous section, pp. 270-289 inc.

and add, drop by drop, dilute sulphuric acid until the liquid acquires a red color. Boil for 10 min. to expel the carbon dioxide. Should the red color pass into blue during the boiling, restore the color by adding a few drops of dilute sulphuric acid. Then add baryta water, drop by drop, until a violet color develops, set aside to deposit, and filter. Preserve the litmus tincture in bottles not completely filled, and preferably covered only with a loose cover.

Magnesia mixture—Dissolve 3 grams calcined MgO in least necessary quantity HCl. Add excess of magnesia and heat. Filter off any precipitated iron, alumina or phosphates and add 35 grams ammonium chloride and 25 cc. of strong ammonia, and dilute to 250 cc. 1 cc. = 0.016 gram P_2O_5

approximately.

Magnesium-nitrate solution—Dissolve 16 grams calcined magnesia in least necessary nitric acid. Add an excess of magnesia, heat for a few minutes, filter and make up 100 cc.

Manganese sulphate solution—for use in iron titrations, to render end-point more distinct. 160 grams of manganous sulphate are dissolved and diluted to 1750 cc. To this are added 330 cc. of phosphoric acid (syrup 1.7 sp. gr.) and 320 cc. of sulphuric acid. About 6 or 8 cc. are used in a titration.

Mercuric-chloride solution—for tin precipitation in iron analysis—7 grams HgCl₂ in 150 cc. water.

Methyl orange—Dissolve the dry substance in water, about 0.3 gram per liter. It must be used in cold solutions. cannot, as a rule, be used with organic acids or with nitrites.

Yellow with alkalis, pink with acids.

Molybdate solution—Dissolve 25 grams molybdic acid (MoO₃) in about 100 cc. ammonia water. If action is too slow, warm and add a little more strong ammonia water. Cool and pour solution, a little at a time, into about 300 cc. of HNO₃ (sp. gr. 1.20). Cool mixture during this process. Dilute to 500 cc. 1 cc. will precipitate about 0.001 gram of phosphorus.

For lead determination dissolve 9 grams of the salt in 1000

cc. water. 1.0 cc. = 0.01 gram Pb.

Nessler's solution—for estimation of ammonia in water analysis. Dissolve 50 grams potassium iodide in a small quantity of hot water, cool, and add with frequent agitation a strong solution of mercuric chloride (40 grams of HgCl₂ to 300 cc. of water until the red precipitate just redissolves. Filter. Add to the filtrate a strong solution of potassium hydrate containing 200 grams of the salt. Filter. Dilute to 1000 cc. and add 5 cc. of a saturated solution of mercuric chloride. Allow the precipitate to settle, decant the clear liquid and keep for use in a tightly stoppered bottle.

Normal acid or alkaline solutions—contain 1.008 grams of

acid hydrogen or 17.008 grams of hydroxyl per liter.

Permanganate solution—for iron, lime, etc.—12 grams KMnO₄ to 2030 cc. water. 1 cc. = 10 mg. Fe. The same solution may be used for lime, 1 cc. = 5 mg. CaO; and for Mn, 1 cc. = 0.002946 gram Mn.

Phenolphthalein—The dry material is dissolved in alcohol, 5 grams per liter. The alcohol may have some acidity which can be removed by boiling, or by redistillation with lime. Cannot be used with ammonia or ammonium salts. Can be used for weak organic acids. Red with alkalis, colorless with

Platinic chloride—Dissolve 1 gram of metal in aqua regia, evaporate to dryness, and dissolve in 1 cc. HCl and 9 cc. H₂O. 1 gram of this solution precipitates 0.048 gram of K₂O.

Salt solution—5.4189 grams per liter. 1.0 cc. = 0.01 mg. of silver. The salt should be dried at about 125°C.

Silver nitrate—1 gram per 20 cc. of water. 1 cc. precipitates **0.0104** gram of Cl.

Sodium chloride—See salt solution.

Stannous chloride solution—Heat 15 grams SnCl₂ and 1 gram pure Sn with 40 cc. water and 10 cc. conc. HCl. Keep

tightly stoppered as it readily absorbs oxygen.

Starch paste—Rub 2 or 3 grams of starch with cold water to a smooth paste which is then added a little at a time to 400 or 500 cc. of boiling water into which it should be thoroughly stirred. After several minutes remove from heat and dilute (if necessary) to 600 cc. and add 5 grams of crystallized zinc chloride. Stir until the zinc salt dissolves, then allow to cool and settle. Decant and bottle the clear liquid for use.

Tannin—for use as indicator in lead assay by titration with ammonium molybdate. Dissolve 1 gram of tannin in 300 cc.

water.

COMMON NAMES AND THEIR CHEMICAL **EOUIVALENTS**

Alum—usually the potassium-aluminum sulphate KAI(SO₄)₂ 12H₂O is meant.

Argols—potassium bitartrate.

Baking soda—sodium bicarbonate.

Bleaching powder—CaOCl₂.

Bluestone—copper sulphate, CuSO₄·5H₂Q.

Calomel—mercurous chloride, Hg₂Cl₂.

Copperas—ferrous sulphate, FeSO₄·5H₂O.

Corrosive sublimate—mercuric chloride, HgCl₂.

Epsom salts—magnesium sulphate.

Eschka's mixture—magnesium oxide and sodium carbonate.

Glauber's salts—sodium sulphate. Green vitriol—ferrous sulphate.

Marignac's salt—potassium stannosulphate, K₂Sn(SO₄)₂.

Microcosmic salt—sodium-ammonium-hydrogen phosphate, HNaNH₄PO₄·4H₂O.

Minium—red lead, Pb₂O₄.

Mohr's salt—FeSO₄·(NH₄)₂SO₄·6H₂O.

Muriatic acid—hydrochloric acid.

Oil of vitriol—sulphuric acid.

Orpiment—yellow arsenic glass. Plaster of Paris—dehydrated gypsum, CaSO₄. Realgar—red arsenic glass.

Rochelle salts—potassium-sodium tartrate, KNaC₄H₄O₆-4H₂O.

Salt of Amber—succinic acid.

Sal ammoniac—ammonium chloride, NH4Cl.

Salts of lemon—acid potassium oxalate, HKC₂O₄.

Salt cake—the residue from nitric-acid making, impure HNaSO₄.

Sal soda—sodium bicarbonate.

Schiff's reagent—ammonium thioacetate solution, CH₃-COSNH₄.

Seidlitz powders—35 grains of tartaric acid and a mixture of 40 grains of sodium bicarbonate with 120 grains of potassium and sodium tartrate.

Soluble water-glass—sodium silicate, Na₂SiO₃.

Sörensen's oxalate—sodium oxalate.

Sugar of lead—lead acetate.

Washing soda—sodium carbonate.

White vitriol—zinc sulphate, ZnSO₄·5H₂O.

The Preparation of Proof Gold¹

The purest gold which can be obtained (usually assay cornets) is dissolved in aqua regia and the excess of nitrie acid expelled by repeated evaporation with additional hydrochloric acid on a water bath. The final solution is then poured in a thin stream into a large beaker full of distilled water, producing a solution of about 1 oz. of gold per pint of water. Stir vigorously and leave the solution to settle. At the end of about a week the chloride of silver will have subsided to the bottom. Remove the clear supernatant liquor with a glass siphon and dilute to about 1 oz. of gold per gallon of water. If the gold originally used was free from platinum, precipitate with sulphurous acid; if platinum was present, precipitate with oxalic acid. Sulphurous acid acts almost immediately, but if oxalic acid is used the solution should be warmed and allowed to stand for 3 or 4 days.

After the precipitated gold has settled the acid solution is siphoned off and the gold transferred to a large flask and repeatedly shaken with cold distilled water, closing the mouth of the flask with a watch-glass. The gold is then washed thoroughly with hot water and turned out into a porcelain basin, dried and melted in a clay crucible and poured into an iron mould, which should be neither smoked nor oiled, but rubbed with powdered graphite and then brushed clean with a stiff brush. The ingot is cleaned by brushing and heating in hydrochloric acid. It is then dried and rolled out. The rolls must be clean and bright and free from grease. The surface of the rolled gold plate is then cleaned by scrubbing with fine sand and ammonia, and also with hydrochloric acid, and is scraped with a clean knife before being used for proof in the bullion assay.

¹ T. K. Rose, "Metallurgy of Gold," fifth edition, p. 488.

Another method is given in the Memorandum by the Assayers of the Melbourne Mint, in the "Annual Report of the Mint." 1913, p. 138. Cornets of gold, derived from the metal obtained by reduction with sulphurous acid, and containing 0.1 per cent. of impurity (chiefly Ag), were treated with cold aqua regia (4:1), the solution largely diluted and allowed to stand for a week to effect separation of silver chloride. Three successive quantities of a dilute solution of silver nitrate (containing Ag 0.5 grain) were then added at intervals of 3 days, the surface of the liquid being gently stirred after each addition, and the whole was allowed to stand for 14 days. Any iridium or other impurity suspended in the liquid was entangled in the precipitated silver chloride; the clear solution was siphoned off. evaporated to dryness and ignited in porcelain; the sponge gold fused in a clay crucible with potassium bisulphate and nitrate, borax added, the melt allowed to cool, the cone of gold treated with boiling hydrochloric acid to remove adhering slag, placed by hand upon borax-glass contained in a clay crucible within a large, covered guard-pot, and melted under conditions precluding contamination of the metal by furnace dust. A slow current of chlorine was then passed through the molten metal for 1 hour, the gas being conducted through a clay tube (1/6-in. bore) by which the gold was continuously stirred. The charge was allowed to cool in the crucible, the cone of gold treated with boiling hydrochloric acid and finally rolled (with special precautions against contamination) into a fillet which was also treated with boiling acid. The original gold weighed 21.5 oz., the finished fillet 21.28 oz., and 0.204 oz. was subsequently recovered from the slag.

The Preparation of Proof Silver

Dissolve commercial fine silver in dilute nitric acid (1:1), and allow the liquid to stand until any fine gold has settled. Siphon off from the gold, dilute with hot water, precipitate the silver with hydrochloric acid, stir well, allow to settle, and wash thoroughly by decantation. When the decanted liquid no longer shows hydrochloric acid, which can be ascertained by testing it with a little silver nitrate, it may be considered clean. Allow the silver chloride to settle and decant off the solution. Transfer the silver chloride to a porous cup which has been soaked in hydrochloric acid and thoroughly washed afterward by standing in frequently changed distilled water. A cathode of pure silver or platinum is placed in the silver chloride and the porous cup immersed in a deeper one, in which a carbon anode is placed. Then a current is started, and silver chloride begins to reduce at the cathode. The outer liquid will become saturated with chlorine and should be renewed from time to time. The silver may then be melted down and rolled as given above under the head of gold. Another method is to use the best obtainable fine silver melted into the form of a cathode about 6 or 8 in. long, about 2 in. wide and 1/4 to 3/8 in. thick. Wrap this in filter paper so that no gold can be detached under electrolysis. The electrolyte is about a 4 per cent. solution of silver nitrate slightly acidulated, and the cathode is pure silver. The current density should be such that the silver is deposited in the form of crystals, which should be later removed, melted and cast, although these crystals may be used themselves in the bullion proof. Still another method of preparing fine silver, due I believe, to A. E. Knorr, is to prepare a solution of silver nitrate from the best commercial fine silver obtainable (material which is already 999 fine) evaporate to remove the excess of nitric acid, and to the neutral solution add enough sodium carbonate to precipitate about one-tenth of the silver present. Boil the precipitate and solution thus produced for some time. The silver carbonate first formed precipitates all other im-Allow to settle, decant carefully (or filter).

The remainder of the silver is then precipitated by chemically pure sodium carbonate. This precipitate carries down a considerable amount of sodium carbonate, but when the material is melted down all of the sodium carbonate comes to the surface as a slag, and can be dissolved off with hydrochloric acid later. The silver carbonate will decompose without the addition of any other reagent if heated sufficiently. The bar produced in this way should be, as said above, cleaned with hydrochloric acid and then rolled, as given above under the

head of the preparation of proof gold.

Assay Fluxes

Basic.—Sodium carbonate (Na₂CO₃)—best used in the anhydrous form.

Sodium bicarbonate (HNaCO₃)—less convenient than the

above as it carries much less soda for the same bulk.

Potassium carbonate (K₂CO₃)—a mixture of sodium and potassium carbonates fuses at a much lower temperature than does either one alone.

Litharge (PbO)—forms exceedingly fusible silicates.

metallic lead with reducing agents, C, S, etc.

Red lead (Pb₂O₄)—same as above, but is more of an oxidizing agent. Carries silver into slag unless completely decomposed.

Lead peroxide (PbO₂)—still more energetic oxidizer.

Hematite (Fe₂O₂)—extremely infusible and must be reduced with carbon in presence of silica in order to work as a flux.

Lime (CaO)—when used with silica and some other base it

forms fusible slags.

Sodium hydrate (NaOH)—used chiefly to decompose sulphides and sulphates, certain silicates and oxides, and organic compounds.

Acid.—Borax (Na₂B₄O₇)—should be fused before use to render it anhydrous. Has the property of holding almost all

oxides in suspension.

Silica (SiO₂)—occasionally used with basic ores to lessen corrosion of crucibles. Better to use glass which carries about 80 per cent. SiO₂.

Glass—see silica.

Neutral.—Fluorspar (CaF₂)—is extremely fusible, and

readily carries phosphates, etc., in suspension.

Common salt—also very fusible but does not dissolve infusible substances readily. Is mainly used as a cover to prevent oxidation of the charge underneath.

Metallic.—Iron—often used in the form of nails to take

care of sulphur.

Lead—used in scorification assay both as a collector of the precious metals and, as it oxidizes, to take care of the gangue. In the crucible assay it is reduced from some oxide as a collector.

Oxidizing.—Niter (KNO₃ or NaNO₃)—at about red heat niter decomposes into potassium nitrite and oxygen, KNO₃ = $O + KNO_2$, at a higher temperature the nitrite also decomposes, $2KNO_2 = K_2O + 2NO + O$.

Lead peroxide (see under basic fluxes).

Manganese dioxide—must be used with some other base, and if any remains undecomposed it appears to carry silver into the slag.

Sodium peroxide—extremely energetic and forms very fusible slags. Especially good in decomposing tin ores, and sulphides,

antimonites, etc.

Approximate Reducing Effect of Various Reducing Agents¹

Reducing agent	Quantity of lead in grams reduced from litharge ² by 1 gram of reagent
Wood charcoal	22–30
Powdered hard coal	
Powdered soft coal	
Powdered coke	24
Argol (crude tartar)	5 - 9.5
Cream of tartar	4.5-6.5
Wheat flour	10.0-12.0
Starch	11.5-13.0
Sugar	12.0-14.5
Potassium cyanide	
Antimonite	6
Blende	7–8
Copper pyrites	7–8
Fahlerz	7–8
Galena	3
Iron pyrites	11
Mispickel	7–8

In Assay Ton Charges

6	per	cent.	FeS	reduces	a	15-gram	button.
		cent.				15-gram	_
7	per	cent.				15-gram	
13	per	cent.	Cu ₂ S			15-gram	
20	per	cent.	PbS	reduces	a	15-gram	button.

¹ For amount of lead reduced from red lead multiply the factors given by 0.55.
2 E. A. Smith's, "Sampling and Assay of the Precious Metals."

Oxidizing Agents (Wet)

Ammonium Nitrate.—Readily decomposes on heating.

Bichromates.—Usually used as the potassium salt.

Bromine.—Usually used as liquid.

Chlorine.—Generated from bleaching powder and sulphuric

Chromates.—Usually used as the potassium salt.
Chlorates.—The sodium or potassium salt is used both in fusion and solution.

Hydrogen Peroxide.—A powerful oxidizer both in alkaline and acid solution.

Nitrates.—The sodium, potassium and ammonium salts are used.

Nitric Acid.—An extremely powerful reagent. The fuming acid is still more so and should be kept in a cool, dark place and handled carefully.

Permanganate.—The alkali-metal permanganates are ener-

getic oxidizers both in acid and alkaline solution.

Peroxides (See also Hydrogen Peroxide).—Sodium and potassium peroxide are energetic agents in alkaline solution. The barium, manganese, lead and sodium peroxides are often used advantageously in fusion.

Reducing Agents

The chief reduction agents in fusions have been spoken of on p. 308. In solution we may use:

Alkaline.—Sodium amalgam, zinc dust, sodium sulphite,

sugar, arsenious acid, sodium stannite.

Acid.—Zinc, iron, tin, aluminum, lead, stannous chloride, sulphur dioxide, sulphuretted hydrogen, hypophosphorous acid, oxalic acid, ferrous sulphate.

NITER REQUIRED TO OXIDIZE 1 PART OF METALLIC SULPHIDE

Sulphide		niter to sulphide	1	of
Iron pyrites	6	$2 -2\frac{1}{2}$		
Mispickel, copper pyrites, fahlerz, blende]	1/2-2		
Antimonite]	1 3/2		
Galena		73		
STOCK FLUXES				

OTOUR THURBS										
ĺ	Sulphide	Tellu	rides	Blend e	m:					
	ores	I	II	Віеп αе	Tin ores					
Litharge Niter Potass. carb Sodium carb Borax glass Sand Charcoal Flour Cover	8 1½ 3 1½ 1½ 1½	10 3 6 0.11 Litharge	30 7 6 51/2 1 Litharge	50 20 20 15 5	60 40 10 1.5 Soda					
Amount for 32 a.t. charge		150 grams	_	75 grams	125 grams					

	Cover	Borax Salt Borax Salt Borax Borax Borax Collect matte and scority with the lead button. Nails if necessary. Nails if necessary. Wet-and-fire method preferable for silver. Salt Scorification preferable. Salt Scorification preferable. Salt Scorification preferable.	
	xarod amarD	121	les ²
	nori to qood		Oxic
CHARGES1	logra amatĐ		Metallic, Oxides
HAR	OiS amarD		Mets
	Grame KNO:	י י י י י י י י י י י י י י י י י י י	Flux 1
RUCIBLE	Grams K,FeCy,		to Fi
CRU	Odd amath	355835 55 88 8 8 8 8 8 8 8 8 8 8 8 8 8 8	_
OF	Grams HNacOs	8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	Required
TABLE	Grama lead flux	30 30 440 20 20 115 30 30	
Ε';	это .j.A	**********	Litharge
	Character of gangue	Neutral, no Pb No bases No bases No bases Basic, no Pb Basic, with BaSO4 Lead, 84 per cent. Siliceous, Pb 42 per cent. None Iron pyrites Siliceous Siliceous	ī
	Ore	Oxidised Quarts Quarts Quarts Guarts Oxidised Oxidised Galena Lead carbonate Copper pyrites Zinky ore Lead matte Copper matte Tellurides Tellurides Arsenical	,

Sn03 13

Cupel Absorption

A safe table for cupel absorption of lead buttons is given in ERNEST A. SMITH'S "Sampling and Assay of the Precious Metals," if there is no great departure from a ratio of height to diameter of 3:4.

As to the cupel absorption of silver and gold, it seems unsafe to give any tables, as this varies with the nature of the material cupelled, the temperature, whether induced draft is used or not, and many other factors. It seems fairly safe to say that a small silver button will lose about 2 per cent., that at 100 mg. the loss will be about 1.5 per cent. and less for larger buttons, and that the gold loss will probably not run over 0.5 per cent., but these figures must be taken as approximations only. It must also be remembered that not all of the button remaining in the cupel is gold and silver. I have usually found about 0.3 per cent. of Pb and Bi as impurity in the silver button; with cement cupels I have found as much as 0.8 per cent. Pb and Bi. The factor is usually neglected in working on comparative tests on different cupels, although both Dewey and I have repeatedly pointed it out.

W. J. Sharwood states (Trans. A. I. M. E., 1915, page 1484) that "when a given amount of silver (or of gold) is cupeled with a given amount of lead, under a fixed set of conditions as to temperature, etc., the apparent loss of weight sustained by the precious metal is directly proportional to the surface of the button of fine metal remaining." From this he deduces that "the loss of weight varies as the ¾ power of the weight, or as the square of the diameter of the button. The percentage loss varies inversely as the diameter of the button, or inversely as the cube root of the weight." This means that, if we run proof assays of any weight whatever, we can deduce the loss of a button of any other weight.

LEAD RETAINED IN THE CUPELLATION OF PLATINUM ALLOYS¹

Composition of alloy		Lead	Character of button		
Pt, mg.	Ag, mg.	Au, mg.	retained, mg.	Character of Dut	ton
100 100 100 100 100 100 100 100	25 50 100 101 206 206 310 427 470	48.0 48.0 6.0	37.5 31.0 26.2 25.0 24.0 22.0 10.0 5.0 2.0	Hard silvery. Hard silvery. Dull gray. Dull gray. Dull gray. Smooth silvery. Smooth silvery. Slightly crystallized. Smooth and silvery. Smooth and silvery.	The lead is almost eliminated with 10 parts of silver to 1 of platinum.

¹ W. J. Sharwood, "Journ. Soc. Chem. Ind.," Apr. 30, 1904, p. 413.

Parting of Gold-Silver Alloys in Nitric Acid¹ after H. CARMICHAEL²

Weight of metals used, milligrams	used,	Rat	io of m	etals	Weight of	Weight of	
Pt	Au	Ag	Pt	Au	Ag	cornet,* Au+Pt	Pt in cornet*
20	100	300	1	5	15	102.7	2.7
15	100	400	1	6.6	26.6	$\left\{ egin{array}{ll} 101.2 \ 100.2 \end{array} ight.$	1.2 0.2
10	100	300	1	10	30	100.8 100.4	0.8 0.4
10	100	500	1	10	50	100.2	0.2
10	200	600	1	20	60	100.0	0.0
14	200	800	1	14.3	57.1	200.3	0.3
14	300	900	1	21.4	64.3	300	0.0
7	100	400	1	14.3		100.2	0.2
5	100	500	1	· 20	100	100	0.0

¹ The first acid was of 1.16 sp. gr., the second of 1.26.
² Taken from Smith's "Sampling and Assay of the Precious Metals"

as were also the next two tables.

The author seems to assume a 100 per cent. gold recovery. This is by no means a sure matter, and all the errors of work are thrown on the results for platinum, which are therefore open to suspicion.

SOLUBILITY OF PLATINUM-SILVER ALLOYS IN NITRIC ACID

Composition	of alloy	Parted in 1.10	HNOs of sp. gr.	Parted in HNOs of 1.40 sp. gr.		
Pt, per cent.	Ag, per cent.	Platinifer- ous resi- due, per cent.	Pt dis- solved, ² per cent.	Platinifer- ous resi- due, per cent.	Pt dis- solved,2 per cent.	
0.5	99.5	0.42	0.08	0.22	0.28	
1.0	99.0	0.85	0.15	0.42	0.58	
2.0	98.0	1.74	0.26	1.09	0.91	
3.0	97.0	2.19	0.81	1.81	1.19	
4.0	96.0	2.98	1.02	2.42	1.58	
5 .0	95.0	3.56	1.44	2.62	2.38	
10.0	90.0		 ••••••••••	4.53	5.47	
13.0	87.0	3.33	9.67	5.79	7.21	
14.0	86.0	4.26	9.74	4.97	9.03	
15.0	85.0	4.32	10.68	7.93	7.07	
16.0	84.0	4.55	11.45	11.54	4.46	
18.0	82.0	4.53	13.46	11.65	6.35	
20.0	80.0			13.94	6.06	
$\frac{25.0}{25.0}$	75.0	16.62	8.38	20.66	4.34	
30.0	70.0	10.02	0.00	29.29	0.71	
31.5	68.5	33.58	2	20.20	V.11	
01.0	00.0	30.00				

¹ Contains Pt and Ag.

² Apparently these figures were arrived at by difference and they are probably unreliable for large weights of residue. See the table following.

Solubility of Platinum-Silver Alloys in Nitric Acid of 1.10 Sp. Gr. (Thompson and Miller's Table)¹

Composition of alloy		Total	Silver in	Platinum	Platinum
Pt, per cent.	Ag, per cent.	residue, per cent.	residue, per cent.	in residue, per cent.	dissolved, per cent.1
10.39 20.59 31.46 37.89 57.05	89.61 79.41 68.54 62.11 42.95	3.86 8.58 36.59 49.13 65.16	0.27 1.81 12.09 13.64 12.19	3.59 6.77 24.50 35.49 52.79	6.80 13.82 6.96 2.40 4.08

Highly Refractory Crucibles

According to Deville a particularly refractory crucible can be made by heating alumina and strongly ignited marble in equal proportions to the highest temperature of the wind furnace, and then using equal proportions of the substance thus obtained with powdered ignited alumina and gelatinous alumina.

Lime crucibles are made by taking a piece of well-burned slightly hydrated lime, cutting it by means of a saw into a rectangular prism 3 or 4 in. on the side and 5 or 6 in. high. The edges are rounded off, and a hole is bored in the center.²

Magnesia Crucibles.—George Weintraub of the General Electric Company, of Schenectady, N. Y., makes refractory articles of magnesia, alumina, thoria, etc., without the use of a binder. The magnesium oxide is first heated in an electric furnace to a high temperature in order to let it assume a stable This firing causes the magnesia to cake together so that regrinding is necessary. It is ground to the fineness of flour in a tube mill. A mould is then made for the article to be produced, say, a crucible. This mould is made of carbon or graphite and a layer of the powdered magnesia is placed on the bottom. A carbon or graphite plug is now placed centrally in the crucible upon this magnesia layer. It is surrounded by a layer of paper which permits the magnesia to shrink when heated. When moulding a crucible of 2½ in. inside diameter, a paper of from 1/6 to 1/8 in. thickness is suitable. The space between the walls of the mould and the paper-covered core is then filled with magnesia powder and packed to a certain degree by shaking and bumping. The mould is now placed in an electric furnace and heated to about 1500°C. When finished and the mould is cooled, the walls of the magnesia crucible contract upon the layer of loose paper carbon, so that cracking is

The solubility of these platinum-silver alloys seems to depend upon the strength of acid used, how the alloy has been annealed, and the amount of gold present, if any.

2 SEXTON, "Fuel and Refractory Materials."

^{*} Metallurgical and Chemical Engineering, Vol. 10, p. 308.

avoided. The finished crucibles are smooth, homogeneous and strong and may be safely handled and may even be worked on the lathe. Tubes may be made in the same way.1

Analyses of Graphite Crucibles²

	1.	2	3	4	5	6	7	8
Al ₂ O ₃		$ \left\{ \begin{array}{l} 7.03 \\ 0.51 \end{array} \right\} $ $ \begin{array}{c} tr \\ 62.54 \end{array} $	1	12.95 50.18	$ \begin{cases} 11.52 \\ 2.79 \end{cases} $ $ 48.68 $	37.09 14.58 44.40 2.92	{ 19.57 } 1.78 } 1.10 42.08	31.31 17.30 47.40 3.42
,	98.66	99.72	98.06	98.79	97.16	98.99	97.13	99.43

WEIGHTS TO BE TAKEN IN SAMPLING ORES

We	eights		Diamet	ers of la	rgest pa	rticle	•
		Very low grade of	Low grade	Mediu	m ores	Rich	Rich
Grams	Pounds	uniform ores, mm.	ores, mm.	Mm.	Mm.	ores, mm.	spotty ores, mm
	20,000.0	207.0	114.0	76.2	50.8	31.6	5.4
	10,000.0	147.0	80.3	53.9	35.9	22.4	3.8
	5,000.0	104.0	56.8	38.1	25.4	15.8	2.7
• • • • • •	2,000.0	65.6	35.9	24.1	16.1	10.0	1.7
• • • • • •	1,000.0	46.4	25.4	17.0 12.0	11.4	7.1	1.2
• • • • • •	500.0	32.8 20.7	18.0 11.4	7.6	8.0 5.1	5.0 3.2	0.85
• • • • • •	$200.0 \\ 100.0$	14.7	8.0	5.4	3.6	2.2	0.38
••••	50.0	10.4	5.7	3.8	2.5	1.6	0.27
••••	20.0	6.6	3.6	2.4	1.6	1.0	0.17
	10.0	4.6	2.5	1.7	î.ĭ	0.71	0.12
	5.0	3.3	1.8	1.2	0.80	0.50	
	2.0	$\begin{bmatrix} \mathbf{\tilde{2}}, \mathbf{\tilde{1}} \end{bmatrix}$	$\tilde{1}.\tilde{1}$	0.76	0.51	0.32	
	1.0	1.5	0.80	0.54	0.36	0.22	}
	0.5	1.0	0.57	0.38	0.25	0.16	
90.0	0.2	0.66	0.36	0.24	0.16	0.10	
45.0	0.1	0.46	0.25	0.17	0.11		
22.5	0.05	0.33	0.18	0.12			
9.0	0.02	0.21	0.11		• • • • • • •		
4.5	0.01	0.15			· · · · · · ·	 • • • • • •	
2.25	0.005	0.10	• • • • • • •		• • • • • •]

¹ U. S. Patent, 1,022,011, April 2, 1912.

² Kerl, "Handbuch der gesammten Thonwaaren Industrie."

1, 2, Hesse; 3, Rhenish; 4, Düsseldorf; 5, German crucible after 18 heats; 6, London (Morgan); 7, English; 8, American.

⁸ Richards, "Ore Dressing," Vol. II.

SIZE-WEIGHT RATIO IN SAMPLING1

Diameter	of largest inches	particle,	Minimum weight of sample, pounds Colorado practice
	0.04		0.0625
	0.08		0.50
	0.16		4.00
	0.32		32 . 00
	0.64		256 . 00
•	-1.25		2,048.00
	2.50		16.348.00

SMALLEST PERMISSIBLE WEIGHT FOR SAMPLES OF A GIVEN SIZE²

Size, inches cube or mesh	Weight of sample, lb.	Ratio of weight of largest cube to weight of sample	Effect on value created by one cube assaying \$100,000 per ton of sp. gr. 5
2	10,000	1: 7,000	\$14.42
11/2	5,000	1: 8,300	12.17
1 1	2,000	1: 11,000	9.00
3⁄4	1,000	1: 13,000	7.50
34 1/2 8/8 1/4 8/16 1/8	400	1: 18,000	5.62
3 /8	. 300	1: 31,000	3.17
1/4	200	1: 71,000	1.40
876	100	1: 83,000	1.20
3/8	75	1: 220,000	0.44
6 mesh	50	1: 430,000	0.23
10 mesh	25	1: 930,000	0.107
18 mesh	10	1:1,900,000	0.051
30 mesh	4	1:4,200,000	0.023
50 mesh	1	1:5,500,000	0.018

SCHEME FOR SAMPLING RICH ORES WITH VEZIN SAMPLERS*

	Inches	Sample, per cent.	Lb. in 100 tons
Maximum size of cubes. Maximum size of cubes. 8 mesh	1.00	0.20	40,000
	0.25	1.25	2,500
	0.0625	0.785	157
	0.0171	0.005	10

¹E. A. Smith, "Sampling and Assay of the Precious Metals."

²R. H. Richards, "Ore Dressing," Vol. III.

³R. H. Richards, "Ore Dressing," Vol. III.

Coal Sampling¹

SIZE OF SLATE CONTAINED IN COAL, AND SIZE OF ORIGINAL SAMPLE REQUIRED TO INSURE THE ERROR OF SAMPLING Being Less Than 1 Per Cent.

Size of slate, inches	Weight of largest piece of slate, lb.	Original sample should weigh, lb.	
4	6.7	39,000	
$ar{3}$	2.5	12,500	
$oldsymbol{2}$	0.75	3,800	
11/2	0.38	1,900	
11/4	0.24	1,200	
1	0.12	600	
3/4	0.046	230	
1/2	0.018	90	

SIZE TO WHICH SLATE AND COAL SHOULD BE BROKEN BEFORE QUARTERING SAMPLES OF VARIOUS WEIGHTS

Weight of sam- ple to be divided, lb.	Should be broken to, inches	Weight of sample to be divided, lb.	Should be broken to, inches
7500 3800 1200 460 180	2 1½ 1 34 34	40 5 1/2 1/4	2 mesh 4 mesh 8 mesh 10 mesh

Coke Sampling²

A point that is of utmost importance in the sampling of coke for blast-furnace use is the ash determination, since every pound of ash in a ton of coke means more expensive fluxing, increased cost of smelting, useless cinder and less furnace capacity available for the production of metal. For this reason differences of opinion as to the ash content of coke for blast-furnace use often cause bitter controversies.

In an investigation of this subject several years ago, I was surprised to find how much of the apparent ash content of coke was due to foreign material introduced in the process of grinding the sample. For instance, the analysis of a sample reported as containing 17 per cent. of ash showed that one-seventeenth of this ash, or 1 per cent. of the weight of the sample, was iron abraded from a Braun pulverizer, while the ordinary cast-iron bucking-board and muller much used in grinding samples to be tested introduces iron into the sample to the extent of from 1/4 to 3 per cent.

<sup>Journ. Ind. and Eng. Chem., p. 161, 1909.
Excerpts from an original article in "Coal Age," July 24, 1915.</sup>

Whether the grinding be done by machinery or by hand, this introduction of foreign matter in grinding can be cut down greatly by the use of manganese- or chrome-steel grinding

plates.

It is impossible to determine the amount of this contamination with a magnet, for the reason that too much coke dust will adhere to the iron filings. It is necessary to treat the sample with a neutral copper-sulphate solution, agitate thoroughly, filter and wash the residue with hot water until entirely free from soluble copper salts. This residue is now dried and ignited and the ash tested for copper or the coke treated directly with nitric acid to dissolve the copper. The weight of copper precipitated by the iron in this process is then calculated from the ratio of

their respective atomic weights.

This method will not answer for the determination of any foreign material introduced by pebble mills, but is very effectual where the grinding surfaces are of iron. It may be objected that the original ash of the coke may have contained some iron which has been reduced to the metallic state by the red-hot carbon of the coke during the coking process. In answer to this argument, any iron in the coke is probably present as ferrous oxide and combined with silica to form ferrous silicate (FeSiO₂). But in any event the objection is not valid, because if the coke sample is crushed in a silica-pebble mill or in an agate mortar, the iron in the coke does not react with neutral copper-sulphate solution.

LIMIT BEYOND WHICH SAMPLES SHOULD NOT BE DIVIDED WHEN CRUSHED TO DIFFERENT SIZES IN LABORATORY

Size of coal mesh	Should not be divided to less than, grams		
2 4 8 10 20	$ \begin{array}{c c} 8300 \\ 1100 \\ 120 \\ 55 \\ 3 \end{array} $ Should be pulverized to at least 60 mesh.		

ETCHING REAGENTS AND THEIR APPLICATIONS¹

Etching Reagents for Iron and Steel

Copper-Ammonium Chloride.—Usually consists of a 10 per cent. solution of the salt in water, and is suitable for wrought iron and mild steel. The specimen is immersed in the solution for about 1 minute, then washed, and the copper deposit, which is readily detached, wiped off under running water. This reagent is used for deep etching effects, and also to darken parts rich in phosphorus.

Copper Chloride.—Dilute acidulated copper chloride in

¹ O. F. Hudson, "Iron and Steel Institute," March, 1915.

alcohol is used by STEAD to detect phosphorus in steels. The reagent is made up as follows:

The salts are dissolved in the least possible quantity of water, and the solution made up to 1000 cc. with alcohol. The purer portions of the steel become coated with copper before the

phosphoric portions.

Hydrochloric Acid.—A dilute solution (1 per cent.) in ethyl alcohol is generally used. Hoyr (c) writes that a solution of 1 cc. hydrochloric acid (sp. gr. 1.19) in 100 cc. absolute alcohol "is recommended for all the iron-carbon alloys whether in a hardened or annealed state," while the action can be accelerated (for special steels) by the addition of a few cubic centimeters of a 5 per cent. solution of picric acid in alcohol.

Iodine.—The ordinary tincture should be used. A simple solution in absolute alcohol is not so suitable. The specimen may be immersed in the solution, or a drop or two placed on the surface to be etched, and allowed to remain until decolorized.

Nitric Acid.—Until the introduction of picric acid, a dilute solution of nitric acid was the principal etching agent for iron and steel, and it is still often used. Solutions (up to about 5 per cent.) in water, or, preferably, alcohol, are generally used. When alcohol is the solvent, absolute alcohol should be used for washing the specimen, and not water. Lantsberry (c), who always uses nitric acid for steels, points out that the success of the method depends on thoroughly washing the specimen with alcohol and drying at once, and that the surface should never be moistened with water.

SAUVEUR (c) writes that for all grades of steel, wrought iron, and pig iron, regardless of treatment, he uses solutions of concentrated nitric acid in absolute alcohol, in proportions varying between 1 and 10 per cent. of acid, according to requirements. He prefers it to picric acid. The samples are washed in absolute alcohol and dried by means of an air-blast. For manganese steel he uses 10 per cent. nitric acid in absolute alcohol, leaving the specimen in the bath until it is covered with a black deposit. It is then washed in alcohol, without any attempt at removing the deposit by rubbing.

Howe (c) uses a solution of 2 per cent. of concentrated nitric acid in water for hardened steels, manganese steels, etc., and also occasionally to develop grain boundaries quickly in low-carbon material, although he notes that it roughens up the ferrite much more than picric acid. He recommends a pre-liminary treatment for the removal of grease, using "alcohol, hydrochloric acid in alcohol, or, best, picric acid in alcohol."

A 4 per cent. solution of nitric acid in iso-amyl alcohol (as suggested by Kourbatoff) is also used, and gives a slow and delicate etching.

⁽c) Information specially communicated for this paper.

Picric Acid.—This reagent, introduced by Ischewsky, is the one most commonly used, generally as a saturated or nearly saturated solution in alcohol. The specimen is immersed for times varying with the kind of steel and the effect desired, from a few seconds for light etching of ordinary rolled or annealed steels and cast irons, to several minutes for hardened steels and wrought irons. Picric acid is sometimes used in conjunction with nitric acid. Thus Desch (c) recommends for all ordinary (unhardened) steels alcoholic picric acid to which a few drops of nitric acid have been added. A solution of picric acid in amyl alcohol is also used for a slow etching. L. Archbutt (c) also finds it "an advantage to add a small quantity of nitric acid, which gives greater certainty of etching, especially in cold weather." The solution he uses contains 80 vols. of picric acid in alcohol and 20 vols. of 2 per cent. nitric acid in alcohol.

ROSENHAIN'S and HAUGHTON'S Reagent consists of:

Ferric chloride	$30 \mathbf{grams}$
Hydrochloric acid (conc.)	100 cc.
Cupric chloride	10 grams
Stannous chloride	$0.5 \mathrm{grams}$
Water	1000 cc.

It is used for determination of the distribution of phosphorus in steel, the purer portions of the steel being stained by deposition of copper, leaving the phosphorus-rich portions white.

Of the numerous other reagents some are used for special purposes, such as sodium picrate, for the detection of cementite; while others are more or less complicated solutions, such as Kourbatoff's reagent, consisting of 3 vols. of a saturated solution of o-nitrophenol in alcohol and 1 vol. of a 4 per cent. solution of nitric acid in alcohol, used for the determination of troostite and sorbite in hardened steels.

Electrolytic Etching

This method is of great value in special cases. Generally a solution of a neutral salt is used as the electrolyte; the specimen is made the anode and a piece of platinum foil the cathode. A feeble current of a small fraction of an ampere is used. Desch (c) finds that etched figures in brasses, etc., are most perfectly developed by electrolytic etching, using a 5 per cent. sodium-chloride solution and a platinum cathode with two dry cells. Other electrolytes used are ammonium nitrate, sodium thio-sulphate (used by Le Chatelier for copper-tin alloys), ammonia, and sometimes very dilute acid solutions.

For Monel metal, L. ARCHBUTT (c) "obtained very good results by electrolytic etching in a solution containing 45 cc. dilute sulphuric acid (1:3) and 5 cc. hydrogen peroxide solution, using a current of 0.1 amp. and 0.5 volt, etching for about 50 seconds. A slight staining of the specimen was subsequently removed by light rubbing with a dilute solution of bromine in hydrochloric acid." Constantan was etched in a similar way, "but stains were removed by using a mixture of dilute sulphuric

acid and hydrogen peroxide and rubbing with the finger." ROSENHAIN (c) has also found that electrolytic etching is useful

for nickel-copper alloys.

Polish Attack.—Used with such success by Osmond and it is one which, if not always applicable, is not adopted as widely as it should be. The objections which appear to be urged against the method are (a) the difficulty of getting uniformly good results, and (b) the danger of obscuring the structure by the flowing action of polishing. Neither of these objections need, however, be serious; the former is overcome by experience, while the latter is probably largely imaginary, unless altogether unnecessary pressure is used. The procedure which has been found suitable for copper and its alloys has already been described in dealing with ammonia as an etching agent. For steels Osmond used a very gentle etching reagent, such as a 2 per cent. solution of ammonium nitrate with precipitated calcium sulphate in parchment, but this method is not now so often used. The author, however, for iron and steel, makes use of parchment thoroughly soaked in water on which a paste of precipitated calcium sulphate is spread. The specimen is then alternately lightly etched with picric acid, and rubbed gently for a few seconds on the parchment. Frequently also it is found to be an advantage to etch the specimen lightly, then polish very gently with alumina and re-etch, repeating if necessary.

GWYER (c) finds that polish attack is sometimes very effective for light aluminum alloys, "for example, in bringing out the structure of the iron-aluminum eutectic. For this washed and ignited magnesia is required, the polishing being done on parchment kept moistened with very dilute caustic soda solution."

GULLIVER (c) notes that sometimes a good polish attack may be obtained with water alone, although not if the pad is new. He found, for example, that polish attack with water alone was

defective in the case of bismuth-tin alloys.

Heat-tinting.—Although not perhaps, strictly speaking, an etching process, heat-tinting is a valuable and widely used method of revealing the structure of alloys, and especially for the detection of small differences in concentration of solid solutions. It consists in heating the specimen until a thin film of oxide is formed on the surface, differences in composition giving rise to variations in thickness, and hence variations in color of the film. Stead used it with great advantage in studying phosphoric cast irons and alloys of iron and phosphorus, and showed that by its use phosphide and carbide of iron could readily be distinguished, while Heycock and Neville proved its value in their work on the copper-tin alloys. Stead has also applied the method to the determination of the distribution of phosphorus in steel. In a paper on "Metallographic Methods for the Detection of Phosphorus in Steel," read before the Cleveland Society of Engineers in December last, STEAD gives details of the heat-tinting method suitable for this purpose. The specimen is floated on a bath of molten tin at a temperature of about 300°C., and allowed to remain until the whole surface

has a reddish-brown color. On examining the specimen, the portions richest in phosphorus will be detected by their blue color, since the parts which are richer in phosphorus than the surrounding metal become colored more quickly. The preliminary treatment of the specimen before it is raised to the tinting temperature is important. Washing with a 1 per cent. solution of picric acid in alcohol is recommended, and the surface should always be "cleaned by rubbing with a clean piece of linen or cotton. The specimen is heated to about 150°C., and then rubbed with a clean piece of chamois leather while still hot." It is then immediately raised to the tinting temperature.

Instead of heating in air, and obtaining a colored oxide film, Stead has shown that other atmospheres may be used, such as sulphuretted hydrogen or bromine. The use of an atmosphere containing bromine for the examination of Muntz

metal has been described recently by STEAD.

Heat-tinting appears to require considerable experience in order to obtain consistent results, and the author, among others cannot rely upon it to be uniformly successful. The following is a summary of the principal reagents for particular metals and alloys.

Etching Reagents Suitable for Particular Metals and Alloys

The following list gives the principal reagents which have been found especially suitable for different metals and alloys:

Copper.—Ammonia (sp. gr. 0.88, diluted 1:1 with water), ammonium persulphate (10 per cent. aqueous solution), bromine (followed by a wash with ammonia), copper-ammonium chloride (5 grams of copper-ammonium chloride in 100 cc. of water, add ammonia until precipitate just dissolves).

Brasses.—Ammonia, ammonium persulphate, copper-ammonium chloride, electrolytic etching, ferric chloride (slightly acidulated with HCl), chromic acid (saturated or nearly saturated solution), nitric acid (strong acid, followed by water), Tinoféef's reagent (94 grams HNO₃ and 6 grams Cr₂O₃, a few drops are used in 50 cc. of water).

Bronzes.—Ammonia, ammonium persulphate, ferric chloride. Copper-Aluminum Alloys (Aluminum Bronzes).—Ammonium persulphate, ferric chloride, copper-ammonium chloride, nitric

acid.

German Silver.—Ammonium persulphate, ferric chloride. Nickel-Copper Alloys, Monel Metal.—Electrolytic etching.

Gold and Rich Gold Alloys, Platinum and Its Alloys.—Aqua regia (dilute, 1 part HNO₂, 5 parts HCl, 6 parts distilled water, used at 15°C.).

Aluminum and Light Aluminum Alloys.—Caustic soda, hydrochloric acid, hydrofluoric acid (1 part fuming HF to 10 or 20 parts of water, clear after treatment by a few second's immersion in HNO₂).

Lead, Tin and Their Alloys (White Metal, etc.).—Chromic acid in nitric acid, ferric chloride, hydrochloric acid, nitric acid,

silver nitrate (5 per cent. solution).

Zinc and Alloys Rich in Zinc.—Caustic soda, iodine (1 part iodine, 3 parts Kl and 10 parts water).

	Given	Sought	Multiply by factor
Aluminum, 27.1	Al ₂ O ₃	Al	0.5303
,	Al	Al ₂ O ₂	1.8856
	AlPO4	Al ₂ O ₂	0.4187
	Al ₂ O ₃	Al ₂ (SO ₄) ₃	3.3504
Antimony, 120.2	Sb_2O_4	Sb	0.7900
,,,,,	Sb ₂ O ₄	Sb ₂ O ₃	0.9474
	Sb ₂ O ₄	Sb ₂ O ₅	1.0526
	Sb ₂ S ₃	Sb	0.7142
	Sb ₂ S ₃	Sb_2O_3	0.8569
	Sb ₂ S ₃	Sb ₂ O ₅	0.9520
	Sb	Sb ₂ O ₃	1.1998
•	Sb	\tilde{Sb}_2O_5	1.3330
Arsenic, 74.96	As ₂ S ₃	As	0.6091
	As ₂ S ₃	As ₂ O ₃	0.8041
•	As ₂ S ₃	As ₂ O ₅	0.9341
• .	As ₂ S ₃	AsO ₄	1.1291
•	As ₂ S ₅	As	0.4832
	Mg ₂ As ₂ O ₇	As	0.4827
	Mg ₂ As ₂ O ₇	As ₂ O ₂	0.6373
	Mg ₂ As ₂ O ₇	As ₂ O ₅	0.7403
	Mg ₂ As ₂ O ₇	AsO ₄	0.8949
•	Managora Managora	As	0.1620
	Ag ₈ AsO ₄	1	1.3202
	As	As ₂ O ₃	1.5336
Danium 127 27	A8	As ₂ O ₄ Ba	0.5885
Barium, 137.37	BaSO ₄		0.6568
-	BaSO ₄	BaO	•
	BaCrO ₄	Ba	0.5422
•	BaCrO ₄	BaO	0.6053
	BaCO ₈	Ba	0.6960
•	BaCO:	BaO	0.7771
Diamonth 000 A	Ba	BaO	1.1165
Bismuth, 208.0	Bi ₂ O ₃	Bi	0.8966
•	BiOCI	Bi	0.8017
	BiOCl	Bi ₂ O ₃	0.8942
•	Bi ₂ S ₈	Bi	0.8122
•	Bi ₂ S ₈	Bi ₂ O ₃	0.9061
	Bi	Bi ₂ O ₈	1.1154
Boron, 11	B_2O_3	B	0.3143
-	B	B_2O_2	3.1818
Bromine, 79.92	AgBr	Br	0.4256
•	AgBr	HBr	0.4309
	Br - Cl	Br	1.7969
	Br - Cl	AgBr	4.2202
•	l Br	01/4	0.1001

Cadmium, 112.4 Caesium, 132.81 Calcium, 40.07	CdO CdS CdS Cd Cs ₂ SO ₄ Cs ₂ PtCl ₄	Cd Cd CdO CdO Cs	0.8754 0.7780 0.8888 1.1424
Caesium, 132.81	CdS CdS Cd Cs ₂ SO ₄	Cd CdO CdO Cs	0.7780 0.8888
	CdS Cd Cs ₂ SO ₄	CdO CdO Cs	0.8888
	Cd Cs ₂ SO ₄	CdO Cs	
	Cs ₂ SO ₄	Cs	T . T
			0.7344
Calcium, 40.07		Cs	0.3943
Calcium, 40.07	Cs	Cs ₂ O	1.0623
Calcium, 40.07	CaO	Ca.	0.7146
•	CaO	CaCO ₂	1.7847
	CaSO ₄	Ca Ca	0.2943
		CaO	
,	CaSO ₄		0.4119
	CaCO ₃	Ca	0.4005
;	CaCO ₃	CaO	0.5603
	Ca	CaO	1.3993
. '	Ca	CaCO:	2.4971
G 1 . 10	CaO	CaC ₂ O ₄	2.2841
Carbon, 12	CaC ₂ O ₄	CO ₂	0.3436
•	CaCO ₃	CO ₂	0.4397
•	$C0^3$	C	0.2727
	C	CO ₂	3.6667
.	CO ₂	CO ₃	1.3636
Chlorine, 35.46	AgCl	Cl	0.2474
	AgCl	HCl	0.2544
,	Ag Cl	Cl	0.3287
		O ₃₄	0.2256
	AgCl	O34	0.05581
Chromium, 52.0	Cr ₂ O ₃	\mathbf{Cr}^{\perp}	0.6842
·	Cr ₂ O ₃	CrO ₃	1.3158
	PbCrO ₄	Cr'	0.1609
•	PbCrO ₄	Cr_2O_3	[0.2351]
	PbCrO ₄	CrO.	[0.3094]
	Cr	Cr ₂ O ₃	1.4615
	Cr	CrO ₃	1.9230
Cobalt, 58.97	CoSO ₄	Co.	0.3804
Ť	Co ₈ O ₄	Co:	0.7343
• }	Co.	CoO	1.2713
	Co(NO ₂) ₃ ·3KNO ₂		0.1303
Copper, 63.57	CuO	Cu	0.7989
	Cu	CuO	1.2517
	Cu ₂ S	Cu	0.7986
	Cu ₂ S	ČuO	0.9996
	CuSCN	Cu	0.5226
	CuSCN	CuO	0.6541

	Given	Sought	Multiply by factor
Cyanogen, 26.01	AgCN	CN	0.19427
Fluorine, 19	Ag CaF ₂	CN F	0.2411 0.4867
	SiF ₄	F	0.7286
Gold, 197.2	Au	AuCl.	1.5395
Hydrogen, 1.008	H ₂ O	H	0.11190
Iodine, 126.92		Ī	0.54055
	Pdl.	Ī	0.7041
	I - CI	I	1.3877
	I - CI	AgI	2.5673
Iron, 55.84	Fe ₂ O ₃	Fe	0.6994
	Fe ₂ O ₃	FeO	0.8998
•	Fe ₂ O ₂	Fe ₈ O ₄	0.9666
	Fe ₂ O ₃	FeS ₂	1.5028
•	FeO	Fe	0.7773
	FeO	Fe ₂ O ₂	1.1114
	Fe8	Fe	0.6352
	Fe	FeO	1.2865
	Fe	Fe ₂ O ₈	1.4298
Lead, 207.2	Pb804	Pb	0.6832
•	PbSO ₄	PbO	0.7360
	PbSO ₄	PbO ₂	0.7887
•	PbSO ₄	PbS	0.7890
	PbCrO ₄	Pb	0.6411
	PbCrO ₄	PbO	0.6906
	PbS	Pb	0.8660
	PbS	PbO	0.9328
	PbCl ₂	Pb	0.7450
	PbO	Pb	0.9283
	Pb	PbO	1.0772
Lithium, 6.94	Li ₂ SO ₄	Li	0.13474
	Li ₂ SO ₄	Li ₂ O	0.29007
	Li ₂ PO ₄	Li	[0.18197]
• ••	Li	Li ₂ O	2.1527
	Li ₂ CO ₈	Li	0.1879
	Li ₂ CO ₈	Li ₂ O	0.4044
Magnesium, 24.32.	Mg ₂ P ₂ O ₇	Mg	0.2184
	$Mg_2P_2O_7$	MgO	0.3621
	Mg ₂ P ₂ O ₇	MgCO ₈	0.7572
	MgSO ₄	Mg	0.20201
	MgSO ₄	MgO	[0.33491]
	MgO	Mg	0.6032
•	MgO	MgCO ₃	2.0912
-	Mg	MgO	1.6579
	<u> </u>	<u></u>	L

	Given	Sought	Multiply by factor N
Manganese, 54.93	Mn ₂ P ₂ O ₇	Mn	0.3869
,	Mn ₂ P ₂ O ₇	MnO	0.4996
	Mn ₃ O ₄	Mn	0.7203
	Mn ₃ O ₄	MnO	0.9301
	MnS	Mn	0.6314
	MnS	MnO	0.8153
	MnSO ₄	Mn	0.3638
	MnSO ₄	MnO	0.4697
	MnO	MnO ₂	1.2256
	Mn	MnO	1.2913
•	Mn	MnO ₂	1.5826
Mercury, 200.6	HgS	Hg	0.8622
,,	HgS	HgO	0.9309
	HgCl	Hg	0.8498
	HgCl	HgO	0.9176
	Hg	HgO	1.0798
Molybdenum, 96.0.	MoO ₃	Mo	0.6667
	PbMoO ₄	MoO ₂	0.3922
Nickel, 58.68	NiSO ₄	Ni	0.3792
	NiO	Ni .	0.7858
•	Ni	NiO	1.2727
Nitrogen, 14.01	NH ₄ Cl	N	0.26186
	NH ₄ Cl	NH.	0.31838
	NH ₄ Cl	NH.	0.33722
	(NH ₄) ₂ PtCl ₆	N	0.06310
	(NH ₄) ₂ PtCl ₄	NH.	0.07672
•	(NH ₄) ₂ PtCl ₆	NH.	0.08126
	(NH ₄) ₂ PtCl ₆	NH ₄ Cl	0.2410
	Pt	N	0.1435
•	Pt	NH ₃	0.1745
	Pt	NH4	0.1848
	N	NH.	1.2158
	NH:	N	0.82247
	N	$(NH_4)_2O$	1.8587
•	N	$(NH_4)_2SO_4$	4.7164
•	i N	N ₂ O ₅	3.8579
	N	NO ₃	4.4261
	N	NO ₂	3.2841
	N	NO	2.1420
Phosphorus, 31.04	Mg ₂ P ₂ O ₇	P	0.2787
	$Mg_2P_2O_7$	P_2O_5	0.6379
·	Mg ₂ P ₂ O ₇	PO ₄	0.8534
	FePO.	P2O5	0.4708
	$U_2P_2O_{11}$	P ₂ O ₅	0.1989
. /			

342 METALLURGISTS AND CHEMISTS' HANDBOOK

•	Given	Sought	Multiply by factor
Phosphorus, 31.04	P2O5	P	0.4369
Distinguis 1050	P	P ₂ O ₅	2.2886
Platinum, 195.2	(NH ₄) ₂ PtCl ₆	Pt D4	0.4396
Potassium, 39.10	K₂PtCl₄ KCl	Pt K	0.4015 0.5244
rotassium, 39.10	KCl KCl	K₂O	0.63170
:	KBr	K	0.3285
	K ₂ 80 ₄	K	0.44870
	K ₂ SO ₄	K₂O	0.5405
	K ₂ PtCl ₄	K	0.1609
	K ₂ PtCl ₄	K₂ O	0.1941
	K ₂ PtCl ₄	KČI	0.3071
	KClO ₄	K	0.28219
	KClO.	K ₂ O	0.33992
	KClO ₄	KCl	0.53811
	K	K ₂ O	1.2046
	КОН	K ₂ CO ₂	1.2315
Rubidium, 85.45	Rb ₂ SO ₄	Rb	0.6401
,,,,,	Rb.PtCl.	Rb	0.2952
	Rb	Rb ₂ O	1.0936
Selenium, 79.2	Se	SeO ₂	1.4040
,	Se	SeO ₃	1.6060
Silicon, 28.3	SiO ₂	Si	0.4693
•	SiO.	SiO ₃	1.2653
•	SiO ₂	Si ₂ O ₇	1.3980
	SiQ ₂	SiO ₄	1.5307
	Si	SiO ₂	2.1308
Silver, 107.88	AgCl	Ag	0.7526
·	.AgCl	Ag ₂ O	0.80843
	AgBr	Ag	0.57444
	AgI	Ag	0.4595
	$\mathbf{A}\mathbf{g}$	Ag ₂ O	1.0742
Sodium, 23.00	NaCl	Na	0.3934
	NaCl	Na ₂ O	0.53028
	Na ₂ SO ₄	Na ·	0.3238
	Na ₂ SO ₄	Na ₂ O	0.4364
	Na ₂ CO ₃	Na	0.43396
	Na ₂ CO ₃	Na ₂ O	0.58491
A.	Na	Na ₂ O	1.3478
Strontium, 87.63	SrSO ₄	Sr	0.4770
	Sr804	SrO	0.5641
•	SrCO ₃	Sr .	0.5936
•	SrCO ₃	SrO	0.7019
	Sr	SrO	1.1826

Given	Sought	Multiply by factor N
BaSO ₄	S	0.13738
BaSO ₄	SO ₂	0.27446
BaSO ₄	SO.	0.34300
BaSO ₄	SO ₄	0.41154
BaSO ₄	H_2SO_4	0.42018
S	SO ₂	1.9978
\mathbf{S}	SO ₂	2.4967
S		3.0585
Te		1.2510
Te		1.3765
TlI	Tl	0.6165
Tl ₂ PtCl ₄	TI	0.5000
Tl	Tl ₂ O	1.0392
ThO ₂	Th	0.8790
	Sn	0.7877
	SnO ₂	1.2693
TiO ₂	Ti	0.6005
WOs	W	0.7930
U_3O_3	U	0.8481
		0.9525
	_	0.8816
	V	0.5604
V		1.7843
V	VO ₄	2.2549
ZnO		0.8034
		0.6709
	•	0.8351
		0.4289
	_	1.2448
_	3	0.7390
, -		0.17452
		0.1848
Pt :	NH ₄ OH	0.35912
Add to the same of	BaSO ₄ BaSO ₄ BaSO ₄ BaSO ₄ BaSO ₄ BaSO ₄ SaSO ₅ SS Te Tl Tl ₂ PtCl ₆ Tl ThO ₂ SnO ₂ Sn TiO ₂ WO ₃ U ₃ O ₅ U ₃ O ₅ U ₄ O ₅ V V ZnO ZnS ZnS Zn ₂ P ₂ O ₇ Zn ZrO ₂ Pt Pt	BaSO ₄ BaSO ₄ BaSO ₄ BaSO ₄ BaSO ₄ BaSO ₄ BaSO ₄ BaSO ₄ SO ₂ SO ₃ SO ₂ SO ₂ SO ₃ SO ₂ SO ₃ SO ₄ Te TeO ₂ Te TeO ₂ Te TeO ₂ Tll Tl ₂ PtCl ₄ Tl Tl ₂ O Th SnO ₂ Sn Sn SnO ₂ TiO ₂ WO ₃ U ₃ O ₅ U ₄ U ₅ O ₅ V V V ₂ O ₅ V V V ₄ ZnO Zn ZnO Zn ZnO ZnO ZrO ₂ Zr Pt NH ₃ NH ₄

Calculated by International Atomic Weight Table of 1915, O=16.

PROPERTIES OF PRECIPITATES!

	Weighed	KaPtCle	私	E MC	over Ke60.	NaCi
A MOLINIA VE I MEGILIALED	Prepared for weighing by	Drying.	Ignition gently Pt. at first. Addi-	sids reduction. Ignition not s- bove a dull red.	Po .	Mention not leading to dell
	Contaminants	Cold, alcoholic, Shightly soluble NaCl and other Drying. sontaining objor-in cold, more so salts (as sulphates) idea or HCl. Salts in bot, H ₂ O. incoluble in alcother than NaCl Solubility in hol. Removed by should be absent creased by alka-washing with H ₂ O. Small amounts of lior soid, dimin-+ NH ₂ Cl+K ₃ Pt-Ca or Mg may be ished by PtCl ₃ Cl ₄ .	As above.	ess NaCl, and if long Ignition not a- KCl or exposed to the air, bove a dull red.	Na.8O, or of non-volatile phates.	KC! and other Ignit; salts (as sulphates above insoluble in alco-red, hol).
	Solutie in	Shightly soluble in cold, more so in bot, HsO. Solubility increased by alkali or soid, diminished by PtCia	As above.	In water. Less in alcohol or strong HCL.	Moderately in E.O. much less in alcohol.	Same se KCl.
	Condittons of solution	Cold, alcoholic, containing chlorides or HCl. Salts other than NaCl should be absent Small amounts of Cs or Mg may be present, but are	As above.	only charides or In water. Less to chlorides should strong HCL.	Absence of salts Moderately in forming non-vols- Hio, much less tile sulphates or in alcohol. contains non-volstile acids (se HaPOs).	Same as KCl.
	Obtained or precipi-	K.PtCl.	K,PtCl	KCI	K,80.	NaCi
	Obtained by or precipitated with	Precipitant Pt- KaPtCla Cla. Frecipitate preferably dis- solved in hot HaO and evapo- rated in a weigh- ed vessel.	Precipitant PtCla	Evaporation and gentle ignition. Volstile at them shows dull red	Evaporation Kabo and ignition. (NEA) COs fa- cilitates conver- sion.	Evaporation NaCl and gentle igni- tion.
	Object	Weigh- ing.	Weigh-	Weigh-	Weigh-	Weigh- ing.
	Ele- ments	M				4 X

t Compiled mainly from an article by Paor. E. Wallen, "Properties of Precipitates," School of Mines Quarterly, Vol. XII, taken from Forman's "Manual of Practical Assaying."

_			5	
Same as EsSO. EsSO. and other Same as EsSO. NasSO. phates.	Ignition, gen-CaO y at first and nally over last-lamp. Addition of Hr- Co, evapora- ion, and igni- ion. In pres-		Ignition, gen-Mg-PiOrtly at first, finally intensely. In presence of Cadd NH4NOs.	erately concentrated by concentration by trated. Free from Prevented by concentrated. Free from Prevented by concentration. Free from Prevented by concentration. Free from Prevented by the free free HCl strong bot HCl kali-earth chlor-presence of C Absence of SiO, and HNOs (di-ides, chlorates, cul-the addition of large amounts of lute). In strong phates, nitrates, HNOs is necessarily significant of large amounts of lute and bareful ferrice. Free free HNOs is necessarily significant of large amounts of lute and bareful ferrice.
804.	tion, ten- t first and I y over lamp. ition of Hr- evapora- and igni- In pres- of C add	Ü	Oct. Inch.	In the
# K	Ignition, gen that it are an finally over blast-lamp. Addition of H 804, evapora- tion, and ign tion. In pre-		Ignition, getty at first, fin by intensely. presence of add NEANO.	ion, I odditiv
Seme	Iguithduly and a second		Ignition, getty at first, fin by intemedy. presence of add NHANO.	Lenit present the HNO
other sul-	which solu- l and n,	Mg- h are	1 3.	separa- and al- nblor- tes, sub- trates, cie, or
Political Parties	A Particular of the particular	and a	Pag 5	of se
Ks90, non-vol phates.	MgCr04, which Ignition, gen-CaO isremoved by solu-tly at first and tion in HCl and finally over represipitation. Addition of Hr-CaSO4, evaporation, and ignition, and ignition, and ignition, In presence of C addition.	BaCO Os. Se resent	SiOs a (OK)s. Usupally	ortant oese on. Alkali ali-car les, obl
9	18 H 18 H	On Carlo	Hot n d (cold cold cold cold cold cold cold cold	By or-postent for pur- lby or-poses of separa Lion. BO, in Alkaline and al HCl kali-earth oblor to HCl kali-earth oblor to Hch idea, chlorates, cul strong phates, intrates read baste, ferrie, o
B Ky8	E E	ln southing In south in hot solu- of NH-Cl uble in + NH-OH (H4)sCO+.	Insolved A NO.	Hradby NO.
Заше з	Hot, strongly am- moniscal and an elightly in Hy- excess of oxalate. CaOt. As above.		Cold, containing Acids. Hot 840, excess of NH4OH+ solutions and (OH)s, NH4Cl. Absence slightly in cold of 830, and bases H4O. Insoluble other than alkalice. in NH4NOs. Akaline and mod. Acids and am.	erately concen-monium salts, portactrated. Free from Prevanted by or-poses ammonium salts. and organic salts. Hot, containing Cone. Hallo, in Alkal some free HCl strong hot HCl knies. Absence of SiO ₃ , and HNOs (di-idea, ollarge amounts of lute). In strong phatel (NHA) Sgroup and hot FerCly and busing. Ca salts.
	124	Alkaline solution Hs(free from large ex-COs. ocea of alkaline and salts, especially ci-tion trates. HsO	ining OH+ bases bases plies	from from Hining Con and Con
M M	Para Para Para Para Para Para Para Para	or in a solution of the soluti	containing (NH,OH+ Absence and bases an alkalies.	Free num anic
Same as KaSOc.	Hot, stro moniscal exosas of As above.	Alkalization of community, on training, on training, on training, on training, on training, on training, on training, on training, on training, on training, on training, on training, on training, on training, on training, or t	Cold, containing moses of NH-OH+NH-Cl. Absence of SiOs and bases other than alkalies. Akaline and mod-	trated. Free from salta and organic selts. Hot, containing some free HCl. Absence of SiOs, large amounts of NAssegroup and Ca. salts.
<u> </u>	"88 ₹	7.5815	1	
Na ₆ 80 ₄	Precipitant CaCo.	Precipitant CaCOs	Precipitant ManHr.	70g m g
-}0g	NAB.	43 d	Precipitant MEN NarHPOL PO.	Ba(OH)s. Precipitant Bago HasOs. Should be heated before
88 K3	Ove.	100	PO.	(4) (5) (4) (4) (4) (4) (4) (4) (4) (4) (4) (4
Same	Precipita (NHJ):CiO, HrCcO, in N OE solution, As above.	Pre (NH)	Na.H	Ba(OH Free H'sSO4 be heat
Weigh- Same as KiBO. NasSO.	Weigh- ing. Weigh- ing.	Separa- tion.	Weigh- ing.	tion. Weigh-
<u> </u>	1.5	-3		3
			Mg	

Continued
PRECIPITATES.
PROPERTIES OF

Ele- ments	Object	Obtained by or precapitated with	Obtained or precipitated as	Conditions of	Soluble in	Contaminants	Prepared for weighing by	Weighed
A					In	ni-pounds. Repeated ci-boiling in very dilute HCl assists in removal, but liable to dissolve some of the precipitate. MgCo, if much is present, and carbonates of the fixed allestes.		•
	Separa- tion.	Precipitant Bacos		Alkaline, contain-HiO ing NH-OH and ing occess of (NH-A)-Lacids CO. And the interpretation of the interpretat	CO. and In hot I. Insolu- I. NHAOH			•
ŝ	Weigh-	Precipitant Fee OE) and NE, OH. Addition of NE, C. aids precipital from.	Fes (OR)	Alkaline, and free from HaS.	Mineral soids Basic ferric and solutions Cr. PrO., Al. containing cit. Zn. Co., Ni. ric, tartario SiOs, etc., Ni. scids, etc., or organic sub-	Ma, Me,	Ignition. presence of HNO, or NI NO, should added. Vola in presence	TO Page
	Bepara-	As above.	Fer(OH)	As above.	As above.	As above.		
	Separa- tion.	Precipitent Fee (OH)n-NaCaHeb. Filt (CaHr-Os)e-n		Dilute contain- In cold ing but little free saids. HCsHsOs. Hot, citrates but too long boil-ganis ing should be stances.	In cold mineral scide. Also in citrates or or- gania sub-	ttle free acids. Also in kalies. SiOs, PrOs, Rot, citrates or or-Al, Cr. Co, Ni, Za, mg boil-ganie aub-Ma, Cu, ebc. Reutld be stance. Insolu-moved by resolu-		

Po.				avoided.	ble in hot very dilute HC, H,O,.	ble in hot very tion and reprecipi-		
¥	Weigh- ing	Precipitant (usual) NH-OE. Best precipitated by adding slight excess NH-OH, boil-	At(OE):	Neutral or alight- ty alkaline, con- taining preferably NH,CL	Adds and fixed alkalies. Slight- ly in cold NHe- OH. Tartrates, citrates, sugar, etc., prevent precipitation.	Neutral or slight- Adds and fixed Basic Al salts; I g n i t i o n In alkaline, con-alkalies. Slight-SiOs, PsOs, Al, Slightly volatile takining preferably by in cold NH- Cr. Co, Ni, Zn, in presence of NH ₄ Cl. OH. Tartrates, Mn, etc. Removed NH ₄ Cl. oftrates, sugar, by resolution and etc., prevent reprecipitation.	I g n i t i o n . Slightly volatile in presence of NH4Cl,	AlsOs
	Separa- tion.		Als (OH) n- (Call - Out a	Same as Fe. No Same as Fe. ex-Same as Fe. free mostio acid cept slightly should be present soluble in hot dilute HC.H.O.	Same as Fe, except slightly soluble in hot dilute HC:H;01.	Same as Fe.		
ర్	Weigh-	Precipitant Cr(OH), NH,OH, Excess removed by boil- ing.		Absence of mein-All acids, in Same as Al. bers of the (NH.); NaOH, KOH, S group, and pref-and elightly in erably all non-NH.OH. Tarvolatile salts. Sol- trates, citrates, ution must be neu-sugar, etc., pretrail.	All acids, in NaOH, KOH, KOH, NAOH, KOH, In- NHAOH, Tar- trates, citrates, sugar, etc., pre- vent precipita- tion.	Strae as Al.	Ignition	CrrO ₃
E	Weigh-	Insoluble form EsTiOs by boiling the solution soldi- fied with HaBOs.		Dilute containing Soluble form Feron, AlrOn, Si- Ignition but little free Hr-same as Fer-Or, and PrOn, Fer-addition SO., ECI and (OH). Insoluble on and AlrOn re-(NH4), CO., chlorides must be ble form by fu-moved by re-soluble form with KH-tion, reduction with KH-tion, reduction facilitates precipi-80, or boiling with SO., and retained. Prolonged with conc. HCl precipitation in	Scluble form 38 me as a fer- (OH). Insolu- ble form by fu- sion with KH- 80, or boiling with conc. HCI	Fe ₁ O ₂ , Al ₂ O ₃ , Si- O ₂ , and P ₂ O ₄ ; Fe ₂ - O ₃ and Al ₃ O ₃ re- moved by re-colu- tion, reduction with SO ₂ , and re- precipitation in	Ignition with TiO, addition of (NH4), CO.	TiO,
	Separa- tuos.	Fusion and leschinguntifil- trate runs cloudy.	(rNaso, Tion)- NatTios	boiling also. Long fusion with Acids. Slightly HrOs. NasCO at high in HsO. Temperature. Temperature. Temperature. Temperature.	or ErsO. Acids. Slightly in H ₁ O.	presence of HCz- HrOz. FesCz, scid-sod- ium silicate, alkali- carth cerbonates,		

PROPRETIES OF PRECIPITATES. Continued

Weighed	042	Gen-MadP,O,
Prepared for weighing by	Ignition; sb-ZaO sence of C is recessary.	
Contaminani	Alkaline carbon- Ignition ato removed by resence of peated washing necessary. With hot HaO. HaO. Feach, AliCa, and SiOt removed by solution and presignited and repression. Removed by resolution, neutralising, and repressipitation. Fe if not previously removed.	phtly None if bases Ignition. reces forming insoluble tly at first. run phosphates are ab- s in-sent and precipi- s in-tate is well washed. I by a of ant. neral Balts of fixed al- ship, balles, Feros, Zno. Ubble HCr. sono.
Soluble in	Silute a cide, ed caustic al- lice, bicarbon- es, and organ- solutions. Silute HCi and NOs, strong iSO, when hot, ee NH, OH re- rds precipital- on.	e en- Acide. Slightly againe, as la amnonium saline, salta. The inspention of amnonium salta in the color of as an analy of a salta the precipitant. HCl Dhute mineral logen acide (especially lower HCl). Insoluble rogen in strong HCs- penta. HNO, and conc.
Conditions of solution	Absence of cause Dilute acide, tic and bicarbon-fixed caustic alsa at a alkalies and kalies, bicarbon-ates, ates, and organic soly with weak or his about tons. Alkaline, or acid Dilute HCf and only with weak or HNOs, atrong game acid. Free HNOs, atrong game acid. Free HNOs, atrong game acid. Free Free NH.OH revent precipitation tards precipitation tards precipitation.	Mn must be endered by the state of the state
Obtained or precipitated se	100 E	
Obtained by or precipitated with	Precipitant ZnCO, Zn(OH); NasCOs, Zn(OH); Has in boiling dilute HC2H30; eolution, NH,Cl facilitates precipitation.	Precipitant Manne, Nanh, HPO, presence of ammonium salts. Br from acetastes of MaO, tate solution KClO, from bolling nitrio-acid solution.
Object	Weigh- ing. Separa- kon	Weigh- ing. Separa- tion
Ele- ments		- Dec

- OS	3K,80, + 2C,80, + C,	R
Drying at gen-Ni the heat. (See Cu.) I g n i t i o n NiO strongly.	Dissolve in dislute Haso, and evaporate in a weighed vessel. Ignition. Same as Ni.	Washing with Cu HyO and then with slookel.
Absence of all Readily in Co, Fe and Zn, Drying at gen-Ni other metals of HNOs. Slowly unless previously the heat. (See Ers and (NHs):25 in a trong generated. Eroupe. Ni pre- Eroupe. Ni pre	Ca and Pb if present. K salts should be removed by careful wrashing. Same as Ni. Ni and other members be no er soft (NH4); group, if not previously removed by separation.	ution HNOs and HCl. As, Sb, or Bi, if Was few Deposit pre-HNOs is not pres-HrO HNOs wanted by Cl. ent. If HNOs and with
Readily in ENO. Slowly in a trong in a trong in a trong in a mile. In ammonium and a transfer, etc. Precipitation prevented by modern or mineral acids. Ecubic in mineral acids.	Hao, acida, NH, Ca and Hand Insoluble in di-should be renditute HCsHrot by caraful and and alcohol. Same as NiB, Ni and member of NH. Hao. (NH,) s gronot previous moved by settlon.	HNOs and HCL. Deposit pre- vented by Cl.
Absence of all Readily in Co, Fe and Zn, Drying other metals of HNOs. Slowly unless previously the heat. He's and (NH4)size of Eroupe. Ni precent as oxalate, sulphate, or double ammonium nitrate, and excess of NH4)He'OH. Bases other than fineral sedds. Alkalina, Fe-Os, from reagents. Absence of other mamonium AleOs, and BiOs strongly. Should be absent. Salta, tartates, from reagents. Absence of other prevented by an d (NH4)sis in mineral sedds. Absence of other prevented by an d (NH4)sis in mineral sedds. Egyptonic (NH4)sis in mineral sedds. Absence of other prevented by an d (NH4)sis in mineral sedds. Egyptonic (NH4)sis in mineral sedds. Egyptonic (NH4)sis in mineral sedds. Egyptonic (NH4)sis in mineral sedds.	Warm, contain-HaO, acida, NE, ing only Co, Ni, and Na salta. and K salta, and Insoluble in discarly saturated lute HCsH-Os with KCzH-POs. Same as Ni. Same as Ni. HaO. HaO.	HaSOs solution containing a few drope of HNOs
E,0	0	ಶ
Electrolysis. Predipitan KOH or NaOH Predipitan His in weak HCsHos nolution.	Precipitant 6KNO, KNO, in solu-Co, tion slightly soid (NO,) with HCaHrOr. Electrolysis. Co Same as NiS, CoS, Ha	Electrolysis. Or
Weigh- ing. Weigh- ing. Bepara- tion.	Weigh- ing. Weigh- ing. Separa- tion.	Weigh- ing.
Z	రి	್ಟ್ರೆ

Continued
PRECIPITATES.
PROPERTIES OF

Weighed			Pb80.	PbCrO4	
Prepared for weighing by	Drying at a temporature which can be borne by the		ignition. If C'Ph8O, in present, treat with ENOs + HsBO,, evaporate, and ignite.	ng on pre-	
Contaminante	preferable. Organ-too strong acid, En are present, En Drying at a ne acids should be or lower oxides will begin to pre-temperature absent. Cu is all precipi-borne by the tated.	Moderately Hot dilute Other members strong HCl or Hr H NO a and of the Has group. SO. If HNO, is strong bot HCl. present, the solution must be cold and dilute.	Histor, Conc. mineral Other sulphates, Ignition. If C little acids; in Nash-which are removed in present, treat r HCl Oz; in NH salts, by washing with with HNOs + ta and and especially very dilute Histor. Histor, evapororganic those of organic	Bi, Ag, Fe, and Moderately Ba, Bi, Hg and Drying on pre- Ba should be ab-strong mineral chromates. If viously weighed sent. Chlorides acids, in hot much Fe is pres-filter, should be absent, N H + C × H + O y, ent, possibly Fer and also alkaline Insoluble in di- (CrO4)a.	Slightly acid, neu- Dilute boiling Other members trai, or alkaline, HNO3; hot conc. of the Haß group Best precipitated HCl. In Nar-if precent, in cold HaßO4 no- SaO4.
Soluble in	too strong seid, or lower oxidos of nitrogen.	Hot dilute HNO, and strong hot HCl.	Conc. mineral acids; in Na.S Os; in NH salts, and especially those of organic soids.	Bi, Ag. Fe, and Moderately Ba, Bi, B Ba ahould be absert, NH Critical acids, in hot much Fe is about be absent, NH (CrH a) rent, possible and also alkaline Insoluble in dis (CrO ₄).	Dilute boiling HNOs; hot conc. HCl. In Nar- SiOs.
	Б.	V Principal	್ಕೆ ಕೆದ್ದ ಕ್ಷಿಕ್ಕಿ	B 수 함 뒤 함 8	25.5
Conditions of solution	preferable. Organic acids should absent.	Moderately strong HClor Hy- SO. If HNO, is present, the solu- tion must be cold and dilute.	D TO TO TO TO	Bi, Ag, Fe, and Moderates about be abstrong minerate. Chlorides acide, in about be absent, NH, C, H and also alkaline Insoluble in cutrates, lute HNO.	Slightly acid, we trad, or alkali Best precipital in cold Hs90.
Obtained Conditions of tated as	preferable. Organic acceptance of absent.		Excess of such but HNOs of NH, sults of socide must	PbCr04	
	preferable. Organic acids should absent.	Precipitant CuS Moderate Has in dilute soid solution. present, the solution must be exampled.	Par of a	R.Cr.O. in acc- tio-acid solution. tio-acid solution. and also alkali	Precipitant Pbs Slightly acid, we Has or alkali Best precipital in cold HasO. lution.
Obtained or precipi- tated as	preferable. Organic accids abould absent.		Excess of such but HNOs of NH, sults of socide must	PbCr04	

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until AgGl fuse. it a ture bove	- . ,	Vola-AssSa AssSa ion.	the the man into a motor of the control of the cont	de light de
# T #		ving.	Dissolving the precipitate in HNOs into a weighed vessel, eva por ating, and igniting alowly at first.	Mixed with 50 Sb ₂ O ₅ ince its weight of HgO and ignited to dull od.
f present ti		sulphides Dr group if the upo	Mg salta, tee, and plate insolu-E	the pre-ti removed o oing the m alcohol, m
Chloride		Ather Haß ment.	Basio Mg sulphates other salts ble in NE sleohol.	S general companies cupitate; by replay H ₂ O by and wash CS ₃ .
Partially in strong hot HCl or HNO. Partially in alkaline and alkaline-earth chlorides. Readily in	NH-OH, KCN, and Na.S.O. Same as AgCl Insoluble in opn- siderable excess of precipitant,	kaline bydrates, of Haß carbonates, and present, supplies In KHSOs, in squaregia, and in HaO+ClorHaO	In warm acids. Basic Mr. salta, In Hio + NH sulphates, and Cl. Insoluble in other salta insoluble in NH OH + also-ble in NH OH	Moderately S generally accommon that a mith 50 acids (HClescripitate; removed of HgO and ignorially). Tarby replacing the nited to dull tare acid essists HsO by alcohol, red, precipitation and weahing with Dissolved by CS. Salar halls or alkaline sul-phides.
Slightly soid with Partially in Chlorides of Pb Ignition HNOs free from strong hot HCland Eg if present the edges of HNOs. Per-in the solution. Volatile tisily in alkaline and alkaline and alkaline and alkaline short ides. Readily in	Same as Agol.	Acid with mineral Soluble in al- acid (preferably kaline bydrates, of carbonates, and pe supplides In KHSOs, in squa regia, and in HSO+Clor HsO	Albeline with In warm acade. Basic NH, OH, contain- In H, O + NH, sulpha ing a minimum of Cl. Insoluble in other as NH, Cl and 30 per NH, OH + aloo-ble in sect. alcohol.	Slightly acid and moderately dilute.
AgGI	AgBr	A818s	MgNH Aso.	#Stage
Precipitant Agol HCl in very slight excess,	Precipitant AgBr NaBr	Precipitant Asses	Precipitant MgClain am- moniacal colu- tion containing alcohol.	Precipitant Shasa Hasin acid solu- tion, or upon acidifying solu- tions of sulph- antimonite.
Weigh-	Separa- tron	Weigh-	Weigh-	Weigh-
*		a.		£

Continued
PRECIPITATES.
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ROPERTI

Weighed	5	MgaPaO,	804	Ċ.
Prepared for Weighing by	members Heating mod-SmOs-group, if erately and slow-Sparat-ly with free ac-Sbass by osse of air. Ad-HyCrOs, dition of HNOs-ag.	Same as Mg. For titration by dissolving in NR.OH and re- ducing by Zu+ H-SO., or by kerdimetry.	Same as BaSO. BaSO.	Same as Ag. AgC!.
Contaminants	Other members of Has group, if present, Separated from Shale by a d d ing HaCaOa, and boiling.	Ameno- in oly beat and Triot.	Same as BaSOs.	Вато на Ад.
Boluble in	Moderately Other mestrong scientific description (HCl especial present. Belly). In boiling ed from Shaolution con -adding H taining free Hrand boiling.	NHADHANDALAL KARINE. Boluble in HCland mod- erately strong H-SOA or HNO. In hot H-O. In- soluble in very dilute HNO.	Same at BaSOs. Same as BaSOs.	Esme as Ag.
Conditions of solution	Moderately di- lute and slightly acid Precipitation promoted by ace- tates and inter- fered with by out- lates or oxalic acid.	Same as Mg. Acid with HNOs, and containing an excess of NHsNOs, and precipitant. Chlorides, HCi, reducing agents and organic acids should be absent.	Same as Ba804.	Same to Ag.
Obtained or precipi- tated as				
Obtained with or precipitated by	Precipitant SnS: Hasin acidachu- tion or upon acidifying solu- tions of alkatine sulpho-s t a n - nate.	Weigh- MgCl ₃ in am- MgNH- ing. ing. ing. containing NH ₄ Cl. Bepara- Precipitant 12MoO- tion and (NH ₄), MoO ₄ in (NH ₄)- tion and (NH ₄), MoO ₄ in (NH ₄)- tion and the solution heated to 80°C. Agitation facilitates these precipits- tion.	Precipitant Basio Backs in hot sol- ution containing a little free HCl.	Precipitant AgCI
Object	Weigh-	Weigh- ing. Bepara- tion and titration.	Weigh- ing.	Weigh- ing.
ESS- ments	0.00 0.00	P4	60 00 00 00 00 00 00 00 00 00 00 00 00 0	5

1 088	600	a.
Ignition after drying. When impurities are present is determined by lose on ignition with HF and Habo.	Absorption in weighed apparatus containing suitable absorbents.	Ignition to Pt (See KaPtCls).
SiO: ing. decid solution zHrO, SiO: Should contain Boiling caustle Inschible s u I - Ignition after SiO: ing. decid solution to dryness and the sting at 115° to 120°C; or by solution of solution of solution of solution of solution of solution of solution of solution of solution to funes of SO: solution to funes function funcs function funcs function functio	from the atmost weighed apparation apparation apparation.	(NH1),Pt. Same as KaPtCle. Same as KaPt. Same as KaPtCle. Ignition to Pt. Cle. Cle.
Boiling caustic fixed alkalies. By fusion with fixed alkalies (caustic or esrbonate). Insoluble in H ₂ O and anids (HF excepted).		Same as KePt- Cle.
Should contain HCL If much HNO, is present, should be removed by adding HCI and boiling.	,	Seme as KaPtCla
zН:О, 8tО₃	Na.CO. K.CO. or Na.CO. Ca.CO.	(NH1),Pt.
Brevaporation of and solution to dryness and heating at 118° to 120°C,, or by evaporation of H ₂ SO ₄ solution to fumes of SO ₄	Absorption NasCOs, with KOH, Na-Ca(OH), NacCos++NaOH.	PtCl.
Weigh-	C, CO ₂ , Weigherto.	Weigh- PtCl.
SiO.	C, CO ₂ ,	z

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Равспритатиом (
QUANTITATIVE

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Bolutian	ny	14	ЪР	3 y	#H	Pď	ପ୍ର	ug	Cu.	Bi	ro.	IL	6-X	αM	ΨZ	Co	IN	eB.
Nitric or sulphuric	:	i	Τ			(g) +	:	:	-1		1	(e) +	:	(9)+	(g) 	:		
Double ammon, oxalate	:	7	İ	1	:		<u> </u>		1		3	1	:	S	1	[]	1	
Double ammon. sulphate	:	:	;	<u> </u>	:		:	:	<u> : </u>	:	::	:	(Ø) —	(v)+	ı	t	11,	:
Double potasa cyanide	Ī	;	;	<u> </u>	:		;		:	<u> </u>					****	:	:	(9)-+
Sulpho-salt	:	:	;				1	Ī		<u>.</u>			* * * * * *			;		******
Glacial phosphoric acid after (NHs)+CO1.	;		:	: :		:	;		1	1			ı	+	ı	1	1	
	1	1	1	1	1		ļ	ļ								1	1	

¹ KARN and Woodsarn, "Journ. Soc. Chem. Ind.," Vol. VIII, p. 266.
— Precipitated on eathode as metal.
+ Precipitated on anode

(a) On anode as 1950s
(b) On anode as 1950s
(c) On anode as 1950s
(d) From alkaline or neutral solution.
(d) From alkaline or neutral solution.
(e) Potass saft preferable
(f) Incompletely. Completely from potase. salt.
(g) After adding NavCeHsOs and HsCalisOs.
(g) Incompletely
(g) Incompletely
(g) Incompletely
(g) Locron Kallina (private communication) called attention to the precipitation of selenium as metal at both cathode and anode. This seems to be the only case where this is true.

SECTION VI

ORE DRESSING

CRUSHING

Stamps, Chilean mills and rolls are used for coarse crushing: feed generally not over 2 in. and discharge screen about 35 to 40 The roll makes less fines in the product than either of the others. HARDINGE mill is a stage crusher; feed about 34 in. product uniform fine sand with but little slime; Huntington mill, regrinding machine; best feed not over 1/4 in. makes considerable slime. Tube mill is best and only logical fine grinding machine.

Abbé Tube Mill.—The original ABBÉ gear-driven mill was supported on a pair of riding rings. The distinguishing feature was a spiral of Archimedes through which the ore was fed and discharged. Tube mills now supported either on riding rings or trunnions. Early tendency was toward long mill of small diameter, 22 ft. by 3½ ft., now changing to 5 and 6 ft. diameter and 16 to 18 ft long. Grinding effected by flint pebbles fed into mill. (See Ball mill.)

Amalgamating Pan.—This is a flat-bottomed iron pan with an iron cone in the center, with high sides, nearly or quite vertical, and in it a horizontal, annular disk, called a muller, is revolved. Many authorities claim that this should not be used as a grinder, but only as an amalgamator. From 3 to 5 hp. is needed for amalgamating, and 5 to 10 hp. for grinding in a 5-ft. pan.

Arrastre.—A machine having horizontal surfaces grinding concentrically on a vertical shaft. In its original form it consists of a circular pavement from 6 to 20 ft. in diameter with a retaining wall around it and a step in the center. the step stands a vertical revolving spindle from which extend horizontal arms, to which large boulders, called dragstones, are attached by chains.

Ball Mill.—Short tube mill (q.v.) of relatively large diameter in which grinding is done by steel balls instead of pebbles. Wet grinding with steel balls formerly considered unwise due

to excessive steel consumption now coming into favor.

Wet grinding with steel balls formerly control to excessive steel consumption now coming Blake Crusher.—Original crusher of crushed between two jaws set at an anging fixed and the other swinging from top suspended imparted to lower end of crushing jaw by by eccentric. (See also Dodge crusher.)

Reven Mill —A form of Chilean mill using the control of Blake Crusher.—Original crusher of jaw type. Rock is crushed between two jaws set at an angle to each other, one fixed and the other swinging from top suspension rod. Motion imparted to lower end of crushing jaw by toggle joint operated

Bryan Mill.—A form of Chilean mill using three rollers instead of two. The wear seems a little more even in this type of mill

than in the Huntington or the regular Chilean.

Chilean Mill (Edge Runner).—These mills have vertical rollers running in a circular enclosure with a stone or iron base or die. They are of two classes: (a) those in which the rollers gyrate around a central axis, rolling upon the die as they go (the true Chile mill; (b) those in which the enclosure or pan revolves, and the rollers, placed on a fixed axis, are in turn revolved by the pan. It was formerly used as a coarse grinder, but is now used as a fine.

Dodge Crusher.—Similar to Blake crusher (q.v.) except movable jaw is hinged at bottom. Therefore discharge opening is fixed giving a more uniform product than Blake with its discharge opening varying every stroke, but this decreases capacity.

Dodge Pulverizer.—A hexagonal barrel revolving on a horizontal axis, containing perforated die plates and screens.

Pulverizing is done by steel balls inside barrel.

Edge Runner.—See Chilean mill.

Fuller-Lehigh Pulverizing Mill.—For coal dust pulverizing only. Used by the Pennsylvania Steel Co., at Lebanon, Penn.

Gardner Crusher.—A swing-hammer crusher, the hammers being flat U-shaped pieces hung from trunnions between two disks keyed to a shaft. When revolved, centrifugal force throws hammer out against feed and heavy anvil inside crusher housing.

Griffin Roller Mill.—A centrifugal mill, like the Huntington except there is one roller only (see "Huntington"). The mill is consequently unbalanced and requires a very solid

foundation.

Gyratory Crusher.—Consists of a vertical spindle the foot of which is mounted in an eccentric bearing. The top carries a conical crushing head revolving eccentrically in a conical maw. There are three types of gyratory: those which have the greatest movement on the smallest lump; those that have equal movement for all lumps; those that have greatest movement on largest lump.

Hardinge Mill.—This is a tube mill made with two conical sections connected by a central very short cylinder. The cone at the feed end is very short so that the large pebbles settle and

grind at the large end where the feed is coarse.

Huntington Mill.—This operates by the centrifugal force of steel rollers revolving against the inner surface of a heavy horizontal steel ring or die. The rollers are suspended upon rods from horizontal arms by short trunnions allowing a swing of the rod and roller in a direction radial from the central vertical shaft.

Kent Roller Mill.—This consists of a revolving steel ring with three rolls pressing against its inner face. The rolls are supported on springs, and the rings support the roll, so that there is some freedom of motion. The material to be crushed is held against the ring by centrifugal force.

Kinkead Mill.—This is a pan mill with a convex conical bottom on which a muller, having two surfaces of different

inclinations, grinds. The machine acts on the gyratory princi-

ple as regards crushing between the surfaces.

Jeffrey Swing-hammer Crusher.—In an iron casing a shaft revolves carrying swinging arms having a free arc movement of 120°. The rotation of the driving shaft causes the arms to swing out and strike the coal or other brittle material, which, when sufficiently fine, passes through the grated bottom.

Krupp Ball Mill.—This is the classic ball mill. Grinding was done by chilled-iron or steel balls of various sizes which ground against each other and the die ring, composed of five perforated spiral plates, each of which lapped the next. This formed steps which gave the balls a drop from one plate to the next, and in addition, gave a space through which oversize was returned. Outside the die-plate is a coarse perforated screen to take the chief wear, while outside that come fine gauze screens. The fines discharge through these into the housing inside which the screens revolve and which has a hopper bottom.

Lane Mill.—A slow-speed roller mill of the Chilean type. horizontal spider carrying six rollers revolves slowly in pan 10 ft: or more in diameter making about 8 r.p.m. Advantages: great crushing weight, low power, decreased wear due to slow

speed.

Marathon Mill.—A form of tube mill used in the cement industry, in which the pulverizing is done by long pieces of

hardened steel shafting.

Marcy Mill.—A ball mill in which a vertical diaphragm is placed about 1 ft. from the discharge end. Between this perforated diaphragm and the end of the tube there are arranged screens for sizing the material, oversize being returned for further grinding while undersize is discharged.

Nissen Stamps.—This is a gravity stamp with an individual

circular mortar for each stamp.

Rolls.—Two cylinders, with faces much less than the diameters, revolving toward each other, drawing the material in between the crushing peripheries. One roll at least usually runs in fixed bearings, the other may or may not run in movable bearings held by springs.

Roll Jaw Crusher.—Same general type as BLAKE and Dodge (q.v.), but moving jaw has rolling instead of oscillating

motion.

Stamp Battery.—In effect a heavy iron pestle working mechanically in a huge iron mortar. Generally grouped in units of five per mortar. Stamps vary up to 2000 lb. in weight, dropping 6 to 8 in. over 100 times per minute.

Sturtevant Balanced Rolls.—All four boxes are movable and held in position by springs. The idea is to divide the thrust whenever the springs yield and, by dividing by two the distance

the roll must move, to reduce internal stresses.

Sturtevant Grinder.—A disk grinder in which one disk is stationary and the other rotates. The stationary disk is moved out of center from time to time, so that any groove which forms can be ground out.

Sturtevant Roll Jaw Crusher.—A crusher in which the motion of the upper part of the jaws is very like that of the Donge crusher, while the lower parts of the jaws, two cylindrical surfaces of varying radii, grind the ore between them.

Sturtevant Ring-roll Crusher.—Works as does the Kent

roller mill, which see.

Symon's Disk Crusher.—A mill in which the crushing is done between two cup-shaped plates which revolve on shafts set at a small angle to each other. These disks revolve with the same speed in the same direction and are so set as to be widest apart at the bottoms. Feed is from the center and the material is gradually crushed as it nears the edge, and is then thrown out by centrifugal force.

Williams Hinged-hammer Crusher.—A machine similar to the JEFFREY machine. There is a rotating central shaft carrying a number of hinged hammers, which fly out from centrifu-

gal force, crushing the feed against the casing.

Crushing with Jaw Crushers

The jaw crusher is probably still the most popular method of reducing the size of ore. A table is given below of what has actually been done with jaw crushers, taken from RICHARD's "Ore Dressing," but the ordinary table of manufacturer's figures on crusher outputs, etc., is omitted for reasons given in part of the general discussion by MILTON H. HELLER in the Engineering

and Mining Journal, Feb. 27, 1915.

When it is observed that the material fed to crushers is for the most part wet, as it comes from the mine, or dampened to reduce the dust, it is apparent the water exerts a lubricating action, which is further augmented should any clayey material be present. This condition might at any time bring the coefficient of friction down to 0.2. Again using RICHARD's formulas, the angle of nip would have to be 11° or under before a bite would occur.

The great variety of shapes and sizes fed to a crusher, as compared with the rather uniform product to the rolls, would indicate that whereas a roll operating with an angle of nip of 16° is just on the danger point, a crusher so operated would have From this reasoning it would appear correct that exceeded it. the angles between the jaws of a crusher should not exceed 12° to work near its utmost capacity.

By referring to the accompanying table, it is readily seen what degree of reduction under present standard measurements of construction will bring the jaw angle about this limit:

DEGREE OF REDUCTION AND JAW ANGLE, BLAKE CRUSHERS

Size of crusher, in.	Actual width opening, in.	Length vertical jaw, in.	Set to crush to, in.	Angle between jaws
4× 7	4	12	1/2	15° 50′
			1	13° 45′
			$\begin{array}{c} 1\frac{1}{2}\\ 2\\ 1\end{array}$	11° 50′
***			2	9° 25′
7×10	61/4	173/2	1	16° 30′
	(-		11/2 2 3 11/2	15° 0′
	İ		2	13° 15′
0.477	014		3	10° 30′
9×15	81/4	24	11/2	15° 25′
			21/2	13° 10′
	ł		2½ 3 4 1½ 3 4 1½ 3 4 5	12° 0′
10.400	017	00	4	9° 30′
10×20	81/2	26	1 1/2	14° 40′
	ļ		ა ა	11° 30′
193/04	111/	90	4	9° 40′
13×24	111/2	33	1 1/2	16° 30′
			3	14° 15′
			4	12° 30′ 11° 0′
15 > 04	. 191/	99	0 11/	
15×24	131/4	33	1 72 2	22° 30′ 21° 45′
			2	20° 30′
		·	o A	18° 30′
•			2 3 4 5 6 7	17° 15′
			e R	15° 20′
			U 7	13° 20′
i			.•	19 90

The manufacturers, no doubt, have exceeded this angle, because it gave them the mouth-size that was sought, for the least cost. The direction that has been taken to increase crusher capacity has been to make a wider jaw. It would have been better if the jaw angle had been made smaller, and the additional iron put into the height of the jaw, rather than the width. The second point, the breaking character of the rock, is important, but is a character outside of our control.

It is readily admitted that a decrease in the size of the discharge opening will reduce the capacity. This amount of reduction is, however, greatly underestimated. Extending the principle given by RICHARDS in Vol. I, p. 35, of his "Ore Dressing," we may argue that in a 15 × 24-in. breaker, if one 15-in. cube reports at the mouth in 125 3-in. cubes, then the capacity at mouth is 125 times that at the throat when breaking to 3 in. If, now, the crushing be reduced to $1\frac{1}{2}$ in., there would be 1000 cubes produced, and the capacity would be 1000 times greater at the mouth than at the throat. The capacity,

then, in the second case would be theoretically but one-eighth

of that in the first case.

With the smaller opening there would be a proportionally larger amount of material that would have to be worked on, as with a smaller opening the probability of more stuff being smaller than that opening would be increased. This would have an added effect in reducing the output. As an illustration of how much this capacity reduction is underestimated, apply the principles stated to the catalog capacity of a 15×24 crusher:

COMPARISON OF CAPACITIES

Approximate capacity for 24 hours

Break to	3 in.	2½ in.	2 in.	
Tons	600	480	420	• • • • •

THEORETICAL

Break to	3 in.	2½ in.	2 in.	11/2 in.
Tons	600	347	177	75

An analysis of a catalog table will show the error of basing estimates upon the figures given.

Approximate Capacity in Tons per day of 10 Hours

Size	Tons	In.	Tons	In.	Tons	In.	Tons	In.
I—7×10	50	2	40	1½	25	1	15	34
II—9×15	120	2½	100	2	80	1½	60	1
III—11×18	200	3	175	2½	150	2	100	114

In case I it is seen that a change from 2-in. to 1-in. product gives 0.5 the output; from 1½ to ¾ in., 0.37 the output. case II, a change from 2 in. to 1 in. gives 0.62 of the output. case III, a change from 3 in. to 1½ in. gives five-tenths (0.5) the output.

There is no consistency in the table, the intermediate size showing less cut than the one larger and the one smaller.

table is in all probability no more than a guess.

Abbreviations.—C. = solid cart-iron frame; Cap. = capacity; Est. = estimated; gris. = grissly; HP. = horsepower; hours; In. = inches; L. = lever pattern; Min. = minute; P. = Pitman pattern; p. = per; picked = poor residue left picking, Rev. = revolutions; B. = sections! boltan frame. CRUSHING WITH BLAKE TYPE OF BREAKERS

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) }

	EST HP.	20 4 7 7 20 85
	Repairs per year exclu- sive of wearing	\$100 (c) None \$155
	Run	Wet Wet Upy Wet Upy Wet Upy Upy Upy Upy Upy Upy Upy Upy Upy Upy
	Est, cap, per Sé hr., tons	125 300 200 200 112–120 200 200 140 150
	Actual cap. per 24 h. per breaker tons	100–120 50 80 3774–40 100 40–50 100 100 100 350
	Crushed to, in.	A Amberiale tenylaterater
Pecklozat Dolved Iraine.	Pond sine	Mine ore over 11% in. gris. Mine ore over 2 in. gris. Mine ore over 2 in. gris. Mine ore picked Mine ore picked Mine ore over 11% in. gris. Mine ore over 11% in. gris. Mine ore over 11% in. gris. Mine ore over 11% in. gris. Mine ore over 11% in. gris. Mine ore over 11% in. gris. Mine ore over 11% in. gris. Mine ore over 11% in. gris.
	Rev. per min.	248000000000000000000000000000000000000
- ravotutions:	Mooth sise, in,	\$6000000000000000000000000000000000000
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3	Diseases No.	

	Est. HP.	-2
	Repairs per year and year excitu- to evia threaw strate	None None Small Small
	Run	
ued	Est. cap. per Sé h., tons	35.0 36.0 100001
ens. Continued	Actual cap. per 24 h. per 24 h. tons	8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
BREAKERS.	Crushed to, in.	11
CRUSHING WITH BLAKE TYPE OF E	Feed zise	Mine ore picked Mine ore over 1½ in. gris. Mine ore over 1½ in. gris. Mine ore over 1 in. gris. Mine ore over 1 in. gris. Mine ore over 1 in. gris. Mine ore (k) On No. I trommel, ½ in. Mine ore (k) On No. I trommel, ½ in. Mine ore (k) On No. I trommel, ¾ in. Mine ore (k) On No. I trommel, ¾ in. Mine ore over 4 in. gris. Mine ore over 4 in. gris. Mine ore over 4 in. gris. Mine ore over 4 in. gris. Mine ore over 4 in. gris. Mine ore over 4 in. gris. Mine ore over 4 in. gris. Mine ore over 4 in. gris. Mine ore over 4 in. gris. Mine ore over 4 in. gris.
'RUSE	Rev. per min.	22.550 27
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	Breaker No.	

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50 24 15 116 110 43 100 75 75 75 75 75 125 62 62
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10 × 15 9 × 15 9 × 15 9 × 12 12 × 12 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 12 × 15 13 × 15 14 × 15 15 × 15 16 × 15 17 × 10 18 × 15 18 × 15 18 × 15 18 × 15 18 × 15 19 × 15 10 × 1

Estimated Cost of Crushing by Jaw Crusher¹

Size of mouth in inches Tons crushed in 24 hours Horsepower Cost of breaker	5	7 × 10 120 8 \$500	9 × 15 192 12 \$750	10 × 20 300 20 \$1050	13 × 30 540 30 \$2250
Cost, cents per ton, oil		0.021	0.021	0.021	0.021
Cost, cents per ton, power Cost, cents per ton, labor	0.773 4.762	0.865 3.333 0.815	0.811 2.083 0.815	0.865 1.333 0.815	0.721 0.741 0.815
Cost, cents per ton, wear Cost, cents per ton, repairs	0.462	0.462	0.462	0.462	0.462
Total cost, cents per ton	6.939	5.631	4.319	3.610	2.895

ESTIMATED COST OF CRUSHING BY SPINDLE BREAKERS²

Number of breaker	$\begin{array}{c} 4 \times 30 \\ 72 \end{array}$	6 × 42 216 9 \$760	8 × 54 540 22 \$1800	6 11 × 72 1080 45 \$3300	8 18 × 126 3000 125 \$7000
Cost, cents per ton for oil Cost, cents per ton interest and	0.021	0.021	0.021	0.021	0.021
depreciation		0.114	0.108	0.099	0.076
Cost, cents per ton, power		0.541	0.541	0.541	0.541
Cost, cents per ton, labor	5.556	1.852	0.741	0.370	0.133
Cost, cents per ton, wear	0.971	0.971	0.971	0.971	0.971
Cost, cents per ton, repairs	0.308	0.308	0.308	0.308	0.308
Total cost in cents per ton	7.556	3.807	2.678	2.310	2.050

PER CENT. OF VOIDS IN CRUSHED LIMESTONE³

Screen opening,	Per cent.	of voids
inches	By water displacement	From specific gravity
36	40.9	46.8
3/8 3/8	39.6	46.1
14	42.2	47.1
3½ 1½ to 3% 2 to ½ 2 to 3½	43.0	45.6
11/4 to 3/4	45.7	44.7
2 to 16	47.9	46.2
2 to 3/4	46.6	46.6
21/4 to 3/8	44.3	42.9
2½ to 1½	46.2	43.4
$\frac{1}{3}$ to $\frac{1}{2}$	46.1	45.1
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	47.5	46.1

¹ R. H. RICHARDS, "Ore Dressing," Vol. I. ² R. H. RICHARDS, "Ore Dressing," Vol. I. ³ RICHARDS, "Ore Dressing," Vol. IV.

An ordinary mine wedge, 8 in. long by 4 in. wide by 2 in. thick at the large end, when caught in 9×15 -in. breakers, takes about as long to work through as does a ton of ore. Moral—remove the wood first.

So far as known, up to the date of writing, July 16, 1915, the largest jaw crusher is one made by the Traylor Engineering and Manufacturing Co., a 66 × 84-in. jaw crusher for the Rockland Lake quarry of the Conklin & Foss Co. on the west bank of the Hudson River just north of Nyack. This crusher, described in detail in the Engineering and Mining Journal of Mar. 27, 1915, is slightly larger than the jaw crushers the Traylor company has previously supplied. The crusher weighs about 520,000 lb. and is approximately 18 ft. high, 26 ft. long and 20 ft. wide. The driving pulley is 12 ft. in diameter and a 350-hp. Westinghouse MS motor will be used to drive the crusher. Fourteen railroad cars were required to transport the crusher from the shops to the quarry, where blockholing and bulldozing will be practically eliminated by the unit.

Symon's Disk Crushers¹

For the work of secondary breaking from a 3- to 5-in. size, to approximately 1½ in., the Symons disk crusher is now being largely used, and has been adopted by the larger mining companies such as Phelps, Dodge & Co., the Guggenheim companies, the Anaconda Copper Co., and the Inspiration Copper Co. Records of the Detroit Copper Co. at Morenci, Ariz., give a life of 170,000 tons for one set of manganese-steel disks, which are the main wearing parts, and cost about \$300. The Federal Lead Co., at Flat River Mo., obtained the low figure of 0.2 ct. per ton for wear over a period of a year.

A test of capacity, power and size of the product of a 48-in. disk crusher was made by David Gilmour, chief engineer for the Guggenheim Exploration Co., with a view to determining the advisability of using it instead of 72 × 20-in. rolls, and as a result the disk crusher was adopted for the Chile Copper Co., at Chuquicamata, Chile. One of the tests was as shown

herewith:

Test of Disk Crusher

Feed, 20 per cent. 4 to 6 in., 50 per cent. 2 to 4 in., 25 per cent. 1 to 1½ in.

Crusher opening, 11/4 in.

Product, 78 per cent. 1/2 to 11/2 in., 22 per cent. 1/2 in. and smaller.

Capacity, 100 tons per hour.

Power, 29 to 47.9 hp.

It will be noted that the rated capacity for this crusher with 1½-in. product is 60 to 80 tons; the power from 50 to 65 hp., so that the catalog ratings are conservative.

In a more practical way the advantages of the disk crusher can be shown by a comparison of costs, which are available for

¹ JULIUS I. WILE, "Tendency of American Milling Machinery Practice," **Eng. and Min. Journ.," Apr. 17, 1915.

1000-ton units for secondary breaking from 3½ into 1½ in. The accompanying estimate is based on the cost of power and repairs only, with 8 hr. crushing and power taken at the low figure of \$50 per hp. per year, the average yearly tonnage being 350,000 tons. The estimate is given for both class A and class B ores, and comparison is made between gyratories, rolls and disk breakers.

CRUSHER ACTION ON VARIOUS ORES-CLASS A

Two No. 5 gyratories, 50 hp. (25 hp. each) 0.24 cts. 0.65 cts.	72 × 16-in. rolls, 60 hp. 0.29 cts. 0.50 cts.	48-in. disk, 40 hp. 0.2 cts. 0.2 cts.
		1
0.89 cts.	0.79 cts.	0.4 cts.
Class B		
Iwo No. 6 gyratories, 66 hp. (33 hp. each)	72 × 20-in. rolls, 80 hp.	48-in. disk, 50 hp.
0.32cts. 1.30cts.	0.39 cts. 1.00 cts.	0.25 cts. 0.40 cts.
	Two No. 6 gyratories, 66 hp. (33 hp. each) 0.32cts.	7wo No. 6 gyratories, 66 hp. (33 hp. each) 72 × 20-in. rolls, 80 hp. 0.32cts. 0.39 cts.

Crushing with Rolls1

0.65 cts.

1.39 cts.

1.62cts.

Total....

According to Philip Argall the most successful dry crusher is the belted roll. They do their best work on $1\frac{1}{2}$ - to 2-in. cubes. In wet crushing they give good results down to 20-mesh and fair down to 40-mesh. According to Mr. Argall the following formulas give the proper roll speed: Let P = peripheral speed in feet per minute; D = diameter of rolls in inches; N = the number of revolutions per minute; S = size in inches of maximum ore cube fed; $S_n = \text{size in inches of maximum cube}$ fed for a given diameter of roll; then

$$100 \times \frac{\log \frac{16}{8}}{\log 2} = P; \ 0.0476 \times D = S_n; \frac{382}{D} \times \frac{\log \left(\frac{16}{8}\right)}{\log 2} = N.$$

The angle of nip for a given particle is the angle between the tangents drawn to the rolls at the points where the particle touches. The most favorable angle is 32°.

The largest particle which can be fed to a set of rolls, according to Haton de la Goupillière is: $\frac{r}{R} > 18 - 19m$; where r = radius of roll, R = radius of largest particle in the feed, and ¹ R. H. Richards, "Ore Dressing," Vol. III.

m = ratio between diameter of the largest grain in crushed product and that of the largest grain in the feed.

The theoretical capacity of the rolls is: $\frac{60PWS}{1728} = C$; where P = peripheral speed in inches per minute, W = width of roll face in inches, S = space between the rolls in inches, and C = capacity in cubic feet per hour.

Size of Feed to Give a 32° Angle of Nip on Different Rolls

Diameter of rolls in inches	Space between the rolls in inches									
	34	5/8	3/2	36	34	36	0			
36 30 26 24 20 16 9	2.23 1.99 1.83 1.74 1.58 1.42 1.14	2.10 1.86 1.70 1.61 1.46 1.29 1.01	1.96 1.73 1.56 1.48 1.32 1.16 0.88	1.84 1.60 1.44 1.36 1.20 1.03 0.75	1.71 1.47 1.31 1.22 1.06 0.90 0.62	1.57 1.34 1.17 1.10 0.94 0.77 0.49	1.45 1.21 1.05 0.96 0.80 0.64 0.36			

SIZE OF FEED TO GIVE A 32° ANGLE OF NIP ON DIFFERENT ROLLS

~	Size of feed to rolls in inches									
Diameter of rolls in inches	11/2	11/4	1	34	3/2	34 -				
		Sp	ace betwee	n rolls (a)					
36 30 26 24 20	0.46 0.280 0.432 0.512 0.666	0.038 0.191 0.270 0.424	0.031 0.185							
16 9	0.822	0.580	0.340	0.101 0.372	0.132					

⁽a) Where blank spaces are left the angle of nip is under 32° with the rolls set close together.

Width of Rolls.—According to RICHARDS the following are the chief considerations. Wide rolls of the same speed have more surface and hence greater capacity. But as width and capacity increase so do the stresses to be met, and consequently the cost of the machine increases. On the other hand, narrow rolls are much easier to keep true, and by running them faster, provided the speed does not exceed the limits for good work, the capacity lost by narrowing can be regained, the stresses are less, and first cost, weight and friction are reduced.

A table of results of roll crushing, taken from RICHARDS,

follows:

GENERAL TABLE OF ROLL DATA

ë ë) _	
- hours; in.	Class (*)	
	Max.	130 70 50 50 250 250 100 190 125
issly; ngs; o	Actual IsutoA	300 300 40 40 100 100 100 100 100 100 100 100
gr. – grissly; h – middlings; ov	Est. horse- power re- quired	100 20 20 8
	Revolutions per minute	100 222 222 223 223 233 243 243 243 243 243
breal	Face width, in.	44404444 4 : : : : : : : : : : : : : : :
Garus breaker; maximum; mid.	Diameter, in.	21222222222222222222222222222222222222
	Space between rolls, in.	CO 26 CO 26
aker; cap. = capacity; est. = estimated; G. = Lowry breaker; mag. = magnetic; max. = number; tr. = trommel.	Product to	Hand jig. No. 1 tr., ½ in. No. 1 tr., ½ in. No. 1 tr., 0.487 in. No. 1 tr., 20, 10, 2 mm. (8.) No. 1 tr., 20, 10, 2 mm. (8.) No. 2 tr., 0.083 in. No. 2 tr., 0.252 in. No. 2 tr., 0.252 in. No. 2 tr., 0.252 in. No. 2 tr., 0.177 in. No. 1 tr., 12 mm. No. 1 tr., 12 mm. No. 1 tr., 7 mm. No. 1 tr., 7 mm. No. 1 tr., 7 mm. No. 1 tr., 7 mm. No. 1 tr., 7 mm. No. 1 tr., 7 mm. No. 1 tr., 7 mm.
Abbreviations.—Bl. = Blake breaker; cap. inches; j.m. = jig middlings; L. = Lower = sectional; th. = through; No. = number;	Feed	From Bl. Th. Bl., 34 in., on No. 1 tr., 15 in. J. m. th. 15 in. Th. Bl., 1 in., on No. 1 tr., 2 mesh. Th. Bl., 1 in., on No. 1 tr., 2 mesh. J.m., 1 to 0.09 in. (a) (b) (c) Th. Bl., 115 in., on No. 1 tr., 0.141 in. Th. Bl., 115 in., on No. 1 tr., 0.141 No. 2 tr., 0.252 in. Ov. of No. 2 tr., 0.252 in. Ov. of No. 2 tr., 0.252 in. J.m., 0.252 to 0.060 in. Th. Bl., 15 in. Ov. No. 1 tr., 0.177 in. Th. Blake., 115 in. (c) No. 1 tr., No. 1 tr., No. 1 tr., No. 1 tr., No. 1 tr., No. 1 tr., No. 1 tr., No. 1 tr., No. 1 tr., Omm. Th. Blake., 115 in. Ov. No. 2 tr., 7 mm.; J.m., 10 to No. 2 tr., Omm. Th. Bl., 15 in., on No. 1 tr., 10 mm. No. 2 tr., Omm. Th. Bl., 15 in., Ov. No. 1 tr., 6 mm. No. 1 tr.,
Abi i	Roll No.	

PI NI NI NI NI NI NI NI NI NI NI NI NI NI		H		- <u>- </u>	1 17 17 17 17 11 11	IV IV III, IV
55 150 100	8 : : :	:	• • •		700 450 300 300	
100 100 150 150 96	42	275	250 30	500	350 150 150 300	300
79. (3) (9)	10	10	80 1 4	100	∞044 	10
848484	35 40 40	40	808	36	855 0 0 2 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	93
488444	1120	14	41 41 41 41	122	84448044	45540
0000000	8222	36	408 404	822 844	188888888 8888888888888888888888888888	88888 8886 8886 8886
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	C 72.75.	*	CC 25 %	SKR C		Close
2 Jig skimmings, 6 mm. to 0. [Jigs. No. 2 tr., 0.224 in. 8 Ov. No. 2 tr., 0.224 in. No. 2 tr., 0.224 in. 1h. Bl., 1½ in., on No. 1 tr., 1½ in. No. 2 tr., 5½ in. 2 Jig tailings, ½ to 2½4 in. No. 9 tr., ½¼ in. (1)	1 Th. Bl., 17 mm. 2 Ov. No. 1 tr., 8 mm. 3 mm. 5 Th. No. 1 tr., 8 mm. 6 mm. 6 mm.	1 Th. gr., 114 in.; th. G. or Bl., 214 No. 1 tr., 25, 15, 10 mm. (8.)	Th. No. 1 rolls on No. 1 tr., 25 mm. No. 1 tr., 25, 15, 10 mm. (8.) 3 J.m., 25 to 7 mm. (8.) No. 1 tr., 25, 15, 10 mm. (8.) 4 J.m., 7 to 0 mm.; ov. No. 3 tr., No. 3 tr., 5, 2½ mm. (8.)	1 Th. Bl., 11% in. 2 J.m., 11% in. to 4 mm. 3 J.m., 4 mm. to 0; j.m., 21% mm. No. 3 tr., 21% mm.	11½ in.; th. gr., 1½ in. No. 10 5 mm. to 5 mm. to 2 mm. 1 in., on No. 1 tr., 0.5 in. No. 5 in. to 0. 11½ in., th. G., 1½ in. No. 1 tr., 15 to No. 1 tr., 15 to No.	3 J.m., 11 to 3 mm. 1 Th. gr., 1 in.; th. G., 1 in. 2 Th. Bl. 2 Ov. No. 1 tr., 0.5 in.; j.m., 0.5 to No. 1 tr., 0.5 in. 0.31 in.

•	ع و	E	NI NI	222					<u>N</u>	IV	
	per tons	.xsM				75	120		125	901	• • •
	Cap. p. 14 h. to. (a)	IsutoA		• • •	• • •	50	120		• •	65	75
	- 0 810	Est. ho power quired		• • •	• • •				10	•	• • •
		Hevoluting 196	40	424 424	0000	94. 94. 11.	100		50	99	30
pa	.ai ,dtb	Free wi	10 15	1225	5555	51.0			15	16	14101
ntinu	.ai ,18	Diamet	20 26	420 420 420 420	8888	888	8888	888	30	30	828
DATA—Continued	etween a.	Space bi	76	Ž ZZ		Close	Close		CI 086	Close	C. 75
GENERAL TABLE OF ROLL D		Product to	No. 3 tr., 0.2 in. No. 1 tr., 25 mm.	No. 1 tr., 25 mm. No. 1 tr., 25 mm. No. 7 tr., 7, 3 mm. (S.)	78 in. 78 in. 215 inm.	400-	5 tr., 3 mr 2 rolls.		No. 5 tr., 16 in. No. 5 tr., 0.1 in.	No. 2 tr., 3 mm.	No. 1 tr., 4 mesh No. 1 tr., 0.224 in. No. 1 tr., 0.224 in.
GEN		Feed	.31 in. to 0 , 1½ in.; Ov. No. 1 tr., 25	.; ov. No. 7 tr.,		Jig tailings, 15 to 8½ mm. From No. 2 Bl., 1 in.	ä	ïr.,	. 1% in. in. to 0; ov. No. 5 tr., 0.1	J.m., 1 in. to 3 mm.; ov. No. 2 tr., No. 2 tr., 3 mm.	Th. Bl. 114 in., on No.1 tr., 4 mesh No. Th. Bl., 114 in. Ov. No. 1 tr., 0.224 in.
	•	Roll No	ო —	64 04		12.	4 mc	104	10 11	=	MH8

in, on No 1 tr, 0 252 m, (f) 102 revolutions per minute caused excessive wear (g) 40 tons for hard ore, 60 for soft. (h) At 35 revolutions the rolls became glazed (i) Ov. No 1 tr., 12 mm; j.m., 12 to 3 mm; poor sand from trunking machine; poor settling table beads (j) Ov No 1 tr., 7 mm, jig tahings, 7 to 3 mm; j.m., 3 to 0 mm. (k) This is the result of actual measurement. (i) Th Dodgs, 144 in, on No 1 tr., 40 mm; ov No, 2 tr., 16 mm., jig tailings, 40 to 60 mm. (m) j.m., 25 mm to sand; ov No 5 tr., 245 mm. (n) Jig middlings, 38 in to 245 mm; ov No 6 tr., 245 mm. (o) Jig tailings, 114 in, to 15 mesh; ov. No. 2 tr., 145 in. (p) This varies from 4, in. down to 20 mesh (q) Ov. No 1 tr., 6 mm, which treats No. 1 roll stuff. (r) The roll classes referred to in the above table 1, II III, IV are I Rolls which crush the product of a breaker, if, Rolls which crush the product of a previous pair of rolls. This may of not of a breaker after it has gone through a tronmet, III Bolls which crush the product of a previous pair of rolls. This may of (a) Actual capacity is what the rolls actually do in 24 hours; maximum capacity is what it is estimated they would do if run at their maximum capacity. (b) Th. Bl., 20 mm; No. 1 mg tailings, 20 to 10 mm; No. 2 m., 10 to 2 mm mm, on No. 2 tr., 10 mm; j.m., 10 to 0 mm (d) One roll makes 44 revolutions, the other 45. (e) Th gr in, on No. 1 tr., 0.252 m, (f) 102 revolutions per minute caused excessive wear. (g) 40 tons for hard ore 35 revolutions the rolls became glazed. (i) Ov. No. 1 tr., 12 mm; j.m., 12 to 3 mm; poor sand from true. a breaker after it has gone through a trommer, III Rolls when the been screened; IV. Rolls that are crushing ig middlings

Tube Mill Data¹

Relation between Per Cent. Ore and Solution, Fineness of Grinding and Horsepower

Screen Analysis of Sand Fed to Tube Mills, 12 ft. Long, 5 ft. Diameter

On 20 On 30 On 40 On 60 On 80 On 100 On 120 On 150 Through 150 6.0 20.0 24.0 23.0 11.0 8.0 4.0 2.0 2.0

VARIABLE PEBBLE VOLUME, FIXED ORE AND SOLUTION

Pounds, pebbles	On 60	On 100	On 150	Through 150	Per cent., ore	Per cent., solu- tion	Tons ore per 24 hr.	Indi- cated horse- power
3,000 6,000 9,000 12,000 15,000 16,800 18,000 20,000 21,000 22,000 23,000 24,000 24,500 25,000 26,000 27,000	42.5 46.5 42.0 32.0 29.0 18.0 3.5 4.0 9.0 6.0 6.0 4.0 3.0 4.0 3.0	27.5 23.5 26.0 32.0 30.0 29.0 28.0 30.0 29.0 20.0 27.0 26.0 28.0 33.0	8.0 8.0 12.0 14.0 15.0 15.0 14.0 16.0 14.0 14.0	22.0 24.0 24.0 27.0 34.0 51.5 55.0 44.0 50.5 50.0 54.0 57.0 57.0 52.0 45.0	63.72 70.17 74.29 60.00 65.38 66.67 66.67 71.88 71.88 71.88 70.37 70.96 68.18 66.67 70.00 68.00	36.28 29.83 25.71 40.00 34.62 33.33 33.33 28.12 28.12 29.63 29.63 29.04 31.82 33.33 30.00 32.00	172 172 172 172 172 172 172 172 172 172	18.80 20.37 22.5 32.16 39.13 42.88 47.16 51.45 56.28 60.10 65.39 77.18 68.61 69.68 75.04 68.60 64.85

VARIABLE ORE AND SOLUTION, FIXED PEBBLE VOLUME

Pounds, pebbles	Feed, inches	Tons ore per 24 hr.	On 60	On 100	On 150	Through 150	Per cent., ore	Per cent., solu- tion	Indi- cated horse- power
20,000 20,000 20,000 20,000 20,000 20,000 20,000 20,000	3 314 314 4 4 414 414	172 172 190 190 216 216 231 231	7.0 13.0 12.5 14.0 16.0 14.0 26.0 30.0	36.0 34.0	11.0 10.0 12.0 14.0 16.0	41.0 41.5 40.0 36.0 34.0 30.0	64.71 66.67 71.05 67.86 68.18 69.70 66.67 72.22	33.33 28.95 32.14 31.82 30.30 33.33	54.28 51.6 54.8 53.2 49.4 47.5

¹ HOFMAN, "General Metallurgy."

VARIABLE SOLUTION, FIXED PEBBLE VOLUME AND ORE FEED

Pounds, pebble	Ore feed, inches	Tons ore per 24 hr.	Tons solu- tion per 24 hr.	On 60	On 100	On 150	Through 150	Per cent., ore	Per cent., solu- tion	Indi- cated horse- power
20,000	2	172	68.0	19 5	38 N	10.0	41.5	71 43	28.57	45.0
20,000	3	172	75.0			12.0			30.44	48.9
20,000	3	172	90.0			13.0			34.33	55.8
20,000	3	172	92.0			14.0			34.80	57.4
20,000	ă	172	98.0			12.0			36.22	58.0
20,000	ä	172	111.0			13.0			39.30	56.9
20,000	3	172	113.0			13.0			39.56	55.0
20,000	3	172	136.0			12.0			44.29	55.8
20,000	3	172	196.0			14.0			52.90	59.0
20,000	ž	172	207.0			13.0			54.60	62.3
20,000	න	172	268.0			12.0			61.10	62.3

Work of Grinding Pan and Tube Mill at Homestake¹

	5-ft. grinding	5 × 14-ft. tube mill			
	pans, 12,308 tons ground by 7 pans	Regular adjustment, medium feed	Special adjustment, heavy feed		
Total tons ground per day Tons ground per day to	19.34 per pan	73	110.0		
pass 200-mesh sieve Water in feed, per cent	10.83 per pan 80–90	43 38	52.8 38.4		

	Head	Tails	Head	Tails	Head	Tails
Assay: gold value per ton. Sising test: per cent. on	\$2.66	\$2.07	\$2.49	\$2.04	\$2.49	\$2.04
50 mesh	47	6.0	39.0	5.0	18.0	7.0
Through 50; on 80	34	14.0	38.0	12.0	49.0	15.0
Through 80; on 100	9 6 4	14.0	12.0	13.0	17.0	14.0
Through 100; on 200	6	26.0	7.0	28.0	11.0	26.0
Through 200	4	40.0	4.0	42.0	5.0	38.0
Tons ground per horse- power per day at one	•					
passage through grinder.				1.94		2.92
To pass 100-mesh sieve		1.31		1.14		1.40
To pass 200-mesh sieve		0.83		0.74		0.97

Material consumed, Pron, worn, 3.41 Iron, scrapped 0.82 Total iron 4.23

Pebbles, 1.66 Pebbles, 1.30

¹ HOFMAN, "General Metallurgy."

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Size of mill	, Clia		Type	Type of ore		- 52	Size of feed	- P	Discharge	Consistency of overflow	Tons per 10 hrs
######################################		Schist and bard quarts. Same ore as above Hard, no talcose metter ', Tough, close-grained quarts. Chunderlee, Australia Hard quarts Brecciated quarts and andente.	nd bard e as abo o talcos close-gr rlee, Au rlee, Au	I quarts ove ove sined q lettelia stralia	itter i quarta i a ia ia ad andegite.		1-in. ring sise. 1-in. ring sise. 94-in. 194-in.	241111	1-in. ring size. 7½-in overflow, no screen. 1-in. ring size. 6-in overflow. 30-mesh ecreen. 24-in. 7½-in. overflow. 1¼-in. 7-in. overflow. 1¼-in. 9-in. overflow. 10-in. overflow.	80 % water 80 % water 82-84 % 80 % water	10.6 113.3 10.6 10.6 10.6 10.6
Sise of		Scree	n analy	nia (not	Screen analysis (not cumulative)	tive)		Rev per.			
tli _m	+30	+40	+60	_	+80 +100 +120 -120	+120	1	min.	Дешелт		
0000 444	0 428 none 0.16	0.858 none 1.05	2 376 0 87 6.33	10.004	13.848 13.017 15.33	3 656	346 13.848 3 656 73.482. 959 13.017 5.952 76.049 06 15.33	00:00	Shows screen is a detriment 6.84 % on 150; 12.25 % on 200, 53.42 through 200	00, 53.42 thro	ugh 200
10-ft.	2.7	2.7	12.0	12.0	11.8	19	61.5	Ø0			

The slow-¹ From original notes of Alexandra McLaren, Litchfield, Conn.
Mr. McLaren says that at least 2 in. of pulp should be kept under the rollers of the slow-speed Lane mill.
speed machine produces a large amount of fine material, but it is not a good regrinding machine.

Barnes-King Development Co., Mont. Argonaut mine, Cal. 62% minus - 200

00 t-

90.0 92.75 61.0

40000 00000

8-118 0404

080 080

408 080

To compare effect of height of decharge

1

	- 200	39.4
	+30 +50 +60 +100 +150 +200 -200	62.0 15.7
duct	+150	100
Size of product	+100	.12.0 25.0 12.6
Sise	09+	n. 4.0 10 17.8 12.0
	+ 50	21 10
	+30	4.0
ç	0.18	Hard Hard Medium Hard
Feed		14-in. 36-in. 4-mesh 115-in
Screen	mesh	30 30 30
Rev. per. Capacity Screen	24 hr.	124 120 75 105
Rev. per.	min.	33 32 32
Grant		Akron 6-ft Akron 6-ft Trent 6-ft Monadnock.
II.JVI		Portland

One horsepower will crush from 1 to 214 tons of ore in the slow-speed mill.

Private notes of H. A. Megraw.

CRUSHING WITH GYRATORY CRUSHERS

Abbreviations.—Br. = breakers; c. = comet; cap. = capacity; est. = estimated; g. = Gates; gris. = grissly; hp. = horsenower: in = inches: L. = Lowry: max. = maximum: No. = number.

	Head raised by		Sorew to 6 in. Screw to 6 in. Screw to 6 in. Screw to 6 in. Screw to 6 in. Shims up to 6 in. Worm gear. 9 and 20. (b) This This is the result of (g) Bevel year and
	beriuper .c	Est. bl	(a) 30 20–25 20 12 12 40 (d) T aths.
	s besides	nisqəA insəw	(c) (d) 20 (f) 24 (g) 11 (g) 12 (h) 46 (h) 46 (g) 8ee Tables or year. (d)
	max. cap. 24 hours, ans	per	(b)960 960 480 380
	cap. per r 24 hours,	Actual br. pe anot	214 200 (b)960 214 250 960 114 110 480 480 175 175 175 114 200 175 380 114 200 34 100 34 100 200 per incidentals, \$200 per Babbitt eccentric every on No. 1 trommel, 1 in.
number.	ot bedarr	o ezig sedoni	234 250 (b)960 (c) (d)30 Worm 24 250 960 (f) 20-25 11 110 480 (f) 20 25 17 2 17 2 17 3 125 380 (g) Screw Scr
- maximum; Mo.	Size of feed		ine ore over 114-in. gris ine ore over 114-in. gris ine ore over 114-in. gris ine ore over 114-in. gris ine ore over 14-in. gris ine ore over 14-in. gris ine ore over 114-in. gris ine ore over 114-in. gris ine ore over 114-in. gris (c) Repairs, oil and ccasional babbitting. (c) Through No. 3 break
= LOWRY; max.	Revolutions per minute	Of bead	C. 1 D 320 160 M G. 1 4 340 170 .M G. 1 3 425 212 M G. 1 3 500 250 M G. 1 3 425 212 M G. 3 6 M C. 1 3 425 212 M C. 2 D M C. 1 D 400 200 M D 20 M L. 1 D 400 200 M M probably crush 1440 tons in 24 hours. all measurement. (e) None except on a coept on gear. on gear. (h) Babbitting bearings. (c)
	Revolut per minu	Of pulley	1 D 320 160 1 4 340 170 2 3 425 212 1 8 500 250 1 8 6 2 D 400 200 1 D 400 200 1 3 are estimates by the moreush 1440 tons in 24 horone exceptions.
inenes; L.	Sire		4 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
1	No.		C. 1 G. 2 G. 2 G. 1 G. 3 G. 3 C. 2 C. 1 L. 1 These are estably orush 1 measurement.
norsepower; 1n.	Pat- tern		can probably binion gear.
norser	.oV 193	Beal	can principle pinion

HARDINGE MILL DATA

_		
Speed, rev. per min.	888888 8	22822888222 228228888222
Charge, balls or pebbles, pounds	85,000 8,000 8,000 8,000 8,000 8,000 8,000 8,000 8,000 8,000 8,000 8,000 8,000	90000000000000000000000000000000000000
Material	Ore from mill bin. Jig tailing Rock-crusher product. Rock-crusher product. Rock-crusher product. Rock-crusher product.	tables Oversise Colbath classifier. Product 16 by 42-in. rolls. Freduct 16 by 42-in. rolls. Jig middling Jig middling Jig middling Jig talling Jig talling Jig talling Wilfley middling
Gangue	Quarts and basalt Siliceous porphyry Quartaose, very hard Quarts and schist Quarts and schist Decomposed porphry and basalt.	Quarts and baselt. Altered schiet. Altered schiet. Quartaite and siderite. Quartaite and siderite. Quartaite and siderite. Guartaite and siderite. Conglomerate Porphyry. Quartaite.
Mining company	Vipond Porcupine Mines Co. Minmi Copper Co. Britannia M & S Co. Melntyre Porcupine Mines. Molntyre Porcupine Mines. Buckhorn Mines Co.	
Туре	Ball Ball Ball Ball Pebble.	Pebble. Pebble. Pebble. Pebble. Pebble. Pebble. Pebble. Pebble. Pebble. Pebble. Tube.
Length cylin- der, inobes	13 16 16 16 16	5222222222222
Diameter of mill, feet	4.00000	♣ € € € € € € € € € € € € € € € € € € €
No.	122 107 156- 192 191	8880 150 150 150 150 150 150 150 150 150 15

* Mill overloaded. • Note R.M.E. * ~ 100 mesh. * ~ 150 mesh.

Continued
DATA
MILL
HARDINGE

upu	Pebbles or balls, pour per ton	00000
Jo.	Elevation feed end inches	#0
p₩	Per cent.	50 50 50 50 50 63 63 50 71.8 71.8 71.8 64 65 65 65 65 65 65 65 65 65 65 65 65 65
qoe	Relative mo	24.2 25.3 25.3 25.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0
	Difference, E.U.	1,143,3 520,2 1,382,0 1,010,2 594,1 668,8 596,4 661,5 700,7 700,7 668,8 858,8 419,8 715,6
83	Evergy un	1,423.4 1,432.4 1,705.1(7) 1,535.6 1,635.6 1,535.6 1,535.6 1,535.6 1,535.6 1,500.0 1,600.0 1,602.1 1,602.1 1,602.1
प्र	Per cept. - 200 met	31212212818282222244 90924900000000000000000000000000
Discharge	Ауегаде .mm.,овів	884445500000000000000000000000000000000
Disc	All pees, .com.	9449418004140041040 8449484446644664466
WQ.	gouth an	280.2 665.3 912.5 313.1 1,002.8(7) 1,154.6 990.3 943.2 1,040.2 1,040.2 1,040.2 1,040.2 1,040.2 1,040.2 1,040.2 1,040.2 1,040.2
2	Average also, mm.	12.00.00 12.
Feed	All peas, and	86.88 12.5.5.5.5.4.5.4.5.6.6.88 1.0.5.4.4.4.5.6.6.5.88 1.0.5.4.4.4.6.6.5.88 1.0.5.6.6.4.5.6.6.5.88 1.0.5.6.6.6.6.6.6.88
10	Tons per	0004440-0000000000-00-00-00-00-00-00-00-
_,	өмөдөөзөН	25.00 25.00
76	Tone, per	48 251 251 150 1150 1101 1101 1111.5 96.36 42.6 42.6
	No.	122 107 155 155 113 113 108 108 108 108 108 124 124 125 125

The "courty units" are calculated on Brantan's rules (cf. "Bag, and Min. Journ." Nov. 21 and 28, 1614). Res for another hand Anteron Gruehing. Crushing. Surface Diagram, "Eng. and Min. Journ." May 24, 1913, and Apr. 13, 1914, and the "Work of Crushing", by Anteron F. Taggarn, "Trans. A. J. M. E.," February, 1914. Esther method gives comparative results, one must be wrong in absolute units, and the arguments are too voluminous to reprint here.

HARDINGE MILL DATA¹

	6 ft. by 16-in. ball mill	8 ft. by 22-in. pebble mill
Average maximum size of feed, mm	44.5 9.0 6.0 0.37 28.9 ²	9.7 1.26 1.5 0.14 37.0 44.3 31.6
Reduction ratio, range	203	0.17 110
Average horsepower	35.06 4	35.6 4.5 1.94 20.5 58.7 27.8

¹ Trans. A. I. M. E., July, 1915. ² Nos. 155 and 191 estimated.

Stamp Milling

Stamp order—Homestake 1 4 2 5 3 Stamp order—Brazil 1 5 2 4 3

Drops per minute—theoretical maximum on 9-in. drop—95.
Drops per minute—theoretical maximum on 8-in. drop— 100 to 108.

STAMP MILL DROPS'

Length of drop, inches	Number of drops per minute	Total inches drop per minute	Compara- tive power required	Number units crushing force per drop	Number units crushing force per minute
6	115	690	100.00	1.0000	115.00
7	108	756	109.57	1.1667	126.00
814	100	850	123.19	1.4167	141.67
1014	90	945	136.96	1.7500	157.50

¹ McFarren's "Stamp Milling and Amalgamation." Courtesy of the "Mining and Scientific Press."

HORSEPOWER PER STAMP REQUIRED BY THE 5-STAMP BATTERY¹

Height of Drop in Inches and Number of Drops per Minute

A. Nominal Horsepower to Raise Stamps without Friction

		,				
Weight of stamp in pounds	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.
	115	110	105	100	95	90
	drops	drops	drops	drops	drops	drops
850	1.234	1.417	1.578	1.717	1.835	1.932
900	1.307	1.500	1.670	1.818	1.943	2.045
950	1.379	1.584	1.764	1.919	2.052	2.159
1000	1.452	1.667	1.856	2.020	2.159	2.273
1050	1.525	1.750	1.949	2.121	2.267	2.386
1100	1.597	1.833	2.042	2.222	2.375	2.500
1150	1.670	1.917	2.134	2.323	2.483	2.614
1200	1.742	2.000	2.227	2.424	2.591	2.727
1250	1.815	2.083	2.320	2.525	2.699	2.841
1300	1.888	2.167	2.413	2.626	2.807	2.955
1350	1.960	2.250	2.506	2.727	2.915	3.068
1400	2.033	2.333	2.598	2.828	3.023	3.182
1450	2.105	2.417	2.691	2.929	3.131	3.295
1500	2.178	2.500	2.784	3.030	3.239	3.409
1550	2.251	2.583	2.877	3.131	3.347	3.523
1600	2.323	2.667	2.970	3.232	3.455	3.636
1650	2.396	2.750	3.062	3.333	3.563	3.750
1700	2.468	2.833	3.155	3.434	3.670	3.864
1750	2.541	2.917	3.248	3.535	3.778	3.977
1800	2.614	3.000	3.341	3.636	3.886	4.091
1850	2.686	3.083	3.434	3.737	3.994	4.204
1900	2.759	3.167	3.527	3.838	4.102	4.318
1950	2.831	3.250	3.619	3.939	4.210	4.432
2000	2.904	3.333	3.712	4.040	4.318	4.545
2050	2.978	3.417	3.805	4.141	4.426	4.659
2100	3.050	3.500	3.898	4.242	4.533	4.772
2150	3.123	3.583	3.990	4.343	4.641	4.886
2200	3.194	3.666	4.084	4.444	4.750	5.000

¹ McFarren's "Stamp Milling and Amalgamation." If the number of drops used varies from that in the table, multiply the horsepower taken from the table by the number of drops used, and divide by the number of drops in the table.

B. Horsepower Applied to Cam-shaft Pulley (1.202 times A)

Weight of stamp in pounds	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.
	115	110	105	100	95	90
	drops	drops	drops	drops	drops	drops
850	1.483	1.703	1.897	2.064	2.206	2.322
900	1.571	1.803	2.008	2.185	2.336	2.459
950	1.658	1.903	2.119	2.307	2.465	2.595
1000	1.745	2.003	2.231	2.428	2.595	2.732
1050	1.833	2.103	2.343	2.550	2.725	2.868
1100	1.920	2.204	2.454	2.671	2.855	3.005
1150	2.007	2.304	2.566	2.793	2.984	3.142
1200	2.094	2.404	2.677	2.914	3.114	3.278
1250	2.182	2.504	2.789	3.035	3.244	3.415
1300	2.269	2.604	2.900	3.157	3.374	3.551
1350	2.357	2.704	3.012	3.278	3.504	3.688
1400	2.444	2.805	3.123	3.400	3.633	3.825
1450	2.532	2.905	3.235	3.521	3.763	3.961
1500	2.619	3.005	3.347	3.642	3.893	4.098
1550	2.706	3.105	3.458	3.764	4.023	4.234
1600	2.793	3.205	3.570	3.885	4.152	4.371
1650	2.881	3.305	3.681	4.007	4.282	4.507
1700	2.968	3.406	3.793	4.128	4.412	4.644
1750	3.055	3.506	3.904	4.250	4.542	4.781
1800	3.143	3.606	4.016	4.371	4.671	4.917
1850	3.230	3.706	4.127	4.492	4.801	5.054
1900	3.317	3.806	4.239	4.614	4.931	5.190
1950	3.404	3.906	4.350	4.735	5.061	5.327
2000	3.492	4.007	4.462	4.857	5.190	5.464
2050	3.579	4.107	4.574	4.978	5.320	5.600
2100	3.667	4.207	4.685	5.099	5.450	5.737
2150	3.754	4.307	4.797	5.221	5.580	5.873
2200	3.840	4.408	4.908	5.342	5.710	6.010

C. APPROXIMATE TOTAL HORSEPOWER (1.35 times A)

THE RESERVE OF THE PERSON NAMED IN COLUMN TWO IS NOT THE PERSON NAMED IN COLUMN TWO IS NAMED IN COLUMN TWO IS NAMED IN COLUMN TWO IS NAMED IN COLUMN TWO IS NAMED IN COLUMN TWO IS NAMED IN COLUMN TWO IS NAMED IN COLUMN TWO IS NAMED IN COLUMN TWO IS NAMED IN COL	~	,				
Weight of stamp in pounds	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.
	115	110	105	100	95	90
	drops	drops	drops	drops	drops	drops
850	1.666	1.913	2.130	2.318	2.477	2.608
900	1.764	2.025	2.255	2.454	2.623	2.762
950	1.862	2.138	2.380	2.591	2.769	2.915
1000	1.960	2.250	2.506	2.727	2.915	3.069
1050	2.058	2.363	2.631	2.863	3.060	3.222
1100	2.156	2.475	2.756	3.000	3.206	3.375
1150	2.254	2.588	2.881	3.136	3.352	3.529
1200	2.352	2.700	3.007	3.272	3.498	3.682
1250	2.450	2.813	3.132	3.409	3.643	3.836
1300	2.548	2.925	3.257	3.545	3.789	3.989
1350	$2.646 \\ 2.744$	3.038	3.383	3.681	3.935	4.143
1400		3.150	3. 50 8	3.818	4.081	4.296
1450	2.842	3.263	3.633.	3.954	4.226	4.449
1500	2.940	3.375	3.758	4.091	4.372	4.603
1550	3.038	3.488	3.884	4.227	4.518	4.756
1600	3.136	3.600	4.009	4.363	4.663	4.910
1650	3.234	3.713	4.134	4.500	4.809	5.063
1700	3.332	3.825	4.260	4.636	4.955	5.217
1750	3.430	3.938	4.385	4.772	5.101	5.370
1800	3.528	4.050	4.510	4.909	5.246	5.523
1850	3.626	4.163	4.635	5.045	5.392	5.677
1900	3.724	4.275	4.761	5.181	5.538	5.830
1950	3.822	4.388	4.886	5.318	5.684	5.984
2000	3.920	4.500	5.011	5.454	5.829	6.137
2050	4.018	4.613	5.136	5.590	5.975	6.291
2100 2150 2200	4.116 4.214	4.725 4.838	5.262 5.387	5.727 5.863	6.121 6.266	6.444 6.597
2200	4.312	4.950	5.512	6.000	6.412	6.750

Mud Sills.—These vary from three to four and range from 12×12 to 24×24 in. These are used only with old-style wooden foundations.

Cross Sills.—These range from 12×16 in. to 20×24 in.

MORTAR BLOCKS1

	How farkened	By wire spikes. By 1-in. bolts. By 30-penny spikes. By 5-in. spikes. By six 1-in. bolts. By three 1 ½-in. bolts.	
	Material	Solid rock Concrete (b) 30 × 30-in. timbers Solid rock	Three timbers 24 × 30-in, timbers 18 × 12-in, timbers Planks
	Foundation	Solid rock Concrete (b) Solid rock Solid rock Solid rock Solid rock Solid rock Solid rock Solid rock Solid rock	Solid rock Solid rock Solid rock Solid rock Solid rock
Width	In.	84६0६६2६ 4054	46084
Wi	Ft.		ପ୍ରପ୍ରପ୍ର
th.	In.	50000 70000 70000 70000	×000%
Length	şi M	(a) (a) (a) (a) (a) (a) (a) (a) (a) (a)	4 (e) 13 5 (e) 10 4
th.	Iņ.	00000000 0000	0000
Depth	É	30455458 0005	*********

(a) With width parallel to cam shaft, (b) 2 ft. thick. (c) For four batteries. (d) Planed and joined. (c) Length over all. The author is in doubt whether these are individual or combined mortar blocks. (f) Levelled by sand. 1 R. H. RICKARDS, "Ore Dressing," Vol. I.

Steam Stamps

The steam stamp is one in which a vertical stamp shaft is forced down to strike its blow, and lifted up preparatory to the next by means of a steam piston. The large ones are used solely in the Michigan Copper Country. A small steam stamp, the Tremain, built by the Gates Iron Works, has been devised for treating gold ore, the idea being that they would be light to pack for the capacity obtained, and could be quickly mounted and dismounted.

STANDARD MINING SCREENS1

Mesh	Wire No.	Diam. of wire, inches	Diam. of aperture, inches	Equivalent in milli- meters	Per cent. of opening
1"	3	0.2437	0.7563	19.81	• • • • • • •
34"	4	0.2253	0.5247	13.33	•••••
5/8"	5	0.2070	0.4180	10.62	
2 mesh	5 8 9	0.1620	0.3380	8.59	• • • • • • • •
$2\frac{1}{2}$	_	0.1483	0.2517	6.39	
3	10	0.1350	0.1983	5.04	• • • • • • • •
31/2	11	0.1205	0.1652	4.20	• • • • • • • •
4	12	0.1055	0.1445	3.67	:
41/2	13	0.0915	0.1307	3.32	
5	13	0.0915	0.1085	2.76	
6	14	0.0800	0.0867	2.20	
6 7 8 9	15	0.0720	0.0709	1.80	• • • • • • •
8	16	0.0625	0.0625	1.59	
	17	0.0540	0.0571	1.45	
10	18	0.0475	0.0525	1.33	
12	19	0.0410	0.0423	1.07	25.80
14	20	0.0348	0.0366	0.93	26.01
16	22	0.0286	0.0339	0.86	30.47
18	23	0.0258	0.0298	0.76	30.24
20	24	0.0230	0.0270	0.69	29.16
22	25	0.0204	0.0251	0.64	31.35
24	26	0.0181	0.0286	0.60	32.27
30	28	0.0162	0.0171	0.43	27.03
40	31	0.0132	0.0118	0.30	21.15
50	34	0.0104	0.0096	0.24	25.00
60	36	0.0090	0.0077	0.20	18.45
64	37	0.0085	0.0071	0.18	• • • • • • •
70	38	0.0080	0.0063	0.16	16.42
80	40	0.0070	0.0055	0.14	19.36

RITTINGER'S sizes: Fine table ore, finer than 0.25 mm.; coarse table ore, 0.25-1 mm.; fine jigging ore, 1-4 mm.; coarse jigging ore, 4-16 mm.; lump ore, 16-64 mm.

¹ R. H. RICHARDS, "Ore Dressing."

TYLER STANDARD SCREEN SCALE

Ratio \sqrt{s}	or 1.414		D : 1
Opening in inches	Opening in millimeters	Mesh	Diam. wire, dec. of an inch
1.050 0.742 0.525 0.371 0.263 0.185 0.131 0.093 0.065 0.046 0.0328 0.0232 0.0164 0.0116 0.0082 0.0058 0.0058	26.67 18.85 13.33 9.423 6.680 4.699 3.327 2.362 1.651 1.168 0.833 0.589 0.417 0.295 0.208 0.147 0.104 0.074	3 4 6 8 10 14 20 28 35 48 65 100 150 200	0.149 0.135 0.092 0.070 0.065 0.036 0.032 0.035 0.025 0.0172 0.0125 0.0122 0.0092 0.0092 0.0042 0.0026 0.0021

I. M. M. STANDARD LABORATORY SCREENS1

Mesh,	Diamete	r of wire	Ape	rture	Screening
linear inch	In.	Mm.	In.	Mm.	area, per cent.
5	0.1	2.540	0.1	2.540	25,00
5 8	0.063	1.600	0.062	1.574	24.60
10	0.05	1.270	0.05	1.270	25.00
$\overline{12}$	0.0417	1.059	0.0416	1.056	24.92
16	0.0313	0.795	0.0312	0.792	24.92
20	0.025	0.635	0.025	0.635	25.00
30	0.0167	0.424	0.0166	0.421	24.80
40	0.0125	0.317	0.0125	0.317	25.00
50	0.010	0.254	0.01	0.254	25.00
60	0.0083	0.211	0.0083	0.211	24.80
70	0.0071	0.180	0.0071	0.180	24.70
80	0.0063	0.160	0.0062	0.157	24.60
90	0.0055	0.139	0.0055	0.139	24.50
100	0.005	0.127	0.005	0.127	25.00
120	0.0041	0.104	0.0042	0.107	25.40
150	0.0033	0.084	0.0033	0.084	24.50
200	0.0025	0.063	0.0025	0.063	25.00

¹ E. A. Smith, "Sampling and Assay of the Precious Metals."

SIZES OF ROUND AND SLOT-PUNCHED PLATE SCREENS

Needle number of screen	Approximate mesh of wire cloth to which openings correspond	Width of slot or diameter of hole in inches	Width of slot or diameter of hole in millimeters
1	12	0.058	1.47
2	14	0.049	1.25
3	16	0.042	1.07
4	18	0.035	0.89
5	20	0.029	0.74
-6	25	0.027	0.69
-7	30	0.024	0.61
8	35	0.022	0.56
9	40	0.020	0.51
10	50	0.018	0.46
11	55	0.0165	0.42
12	60	0.015	0.38
13	70	0.013	0.33

The needle-number is the number of the standard sewing needle that will just pass the screen.

Table taken from MacFarren's "Stamp Milling and Amalgamation."

CONCENTRATION

The processes by which concentration may be carried on are: hand picking, wet-gravity separations (jigging, vanning, etc.), amalgamation, magnetic, electrostatic, pneumatic, adhesion or flotation, crushing and screening, decrepitation and screening, by varying electric conductivity. A short list of the chief

concentrating machinery follows:

Ball-Norton Magnetic Separator.—This consists of two volving drums. Within each of these drums is a series of revolving drums. stationary electromagnets extending the working length of the drum, but corresponding only to a portion of the periphery. The ore is fed on the top of the first drum, and as the drum revolves, the magnetic particles adhere to it, while the nonmagnetic fall into a tailings bin below. The magnetic particles, as soon as the portion of the drum on which they are passes beyond the magnets, are thrown off by centrifugal force against the second drum. This either rotates faster or has a weaker magnetic field than the first drum, so that those particles least strongly attracted by the first drum fall from the second, making a middlings product.

Bartlett Table.—This is a three-deck WILFLEY, the second deck re-treating the material from the first and the third deck re-treating the material from the second. An in amount of wash water is used on the successive decks. An increasing

Bilharz, Corning, Luhrig and Stein Tables. - These are sidebump tables having a table surface made of an endless traveling belt which has a plane surface.

Bumping and Jerking Tables.—These machines use mechanical agitation to bring the light and the heavy grains into their respective layers on a washing surface, and they use a bumping or jerking action to convey the heavy grains to one side or the other of the machine, while the current of surface water conveys the light grains to another side or end. They may be either side-bump, having the bump or jerk at right angles to the flow of the water, or end-bump, having the bump or jerk in the opposite direction from the flow of the water. See RITTINGER, BILHARZ, WILFLEY, BARTLETT and OVERSTROM for side-bump tables. For further information see these types and "end-bump" tables.

Canvas Tables.—These are inclined rectangular tables covered with canvas. The pulp, to which clear water is added if necessary, is evenly distributed across the upper margin. As it flows down, the concentrates settle in the corrugations of the canvas. After the meshes are filled, the pulp feed is stopped, the remaining quartz is washed off with clear water, and finally

the concentrates removed (by hose or brooms).

Card Concentrator.—A table made of two planes having a flexible joint between them dividing the table into two nearly equal triangles, forming a diagonal line along which concen-

trates and tailings part company.

Conkling Magnetic Separator.—The ore is fed on a conveying belt which passes under magnets, below which belts run at right angles to the line of travel of the main belt. The magnetic particles are lifted up against these cross belts and are thus removed.

Deister Table.—This is a riffled table in which the angle between the line of termination of the riffles and the direction of motion is not so acute as in the WILFLEY. It is also wider and

shorter. The top is rhomboidal.

Ding's Magnetic Separator.—Material is fed up a vibrating conveyor and passes through successive zones of separation. These zones are covered by the rims of rotating wheels which carry secondary magnets. These carry the magnetic particles out of the field, are demagnetized, and drop the concentrates.

Dodd Buddle.—A round table resembling in operation a Wilfley table, and also like the Pinder table (q.v.) except that it is convex instead of concave. The table does not revolve but has a peripheral jerking motion imparted to it circumferentially

by means of a toggle movement.

End-bump Tables.—The heavy and light minerals are separated by agitation and are propelled up the slope of the table by bumping action, but the wash water carries down the surface quartz at a higher speed than the bump can send it up. The Gilpin County, IMLAY and Golden Gate concentrators are the chief types.

Ferraris Table.—This table has a plane rubber belt traveling between rollers furnished with broad flanges to keep the belt in line. It has a slope from side to side. The feed is at an upper

corner, and washing is by jets directed across the table.

Film-sizing Tables.—These use the relative transporting power of a film of water flowing on a quiet surface, which may be either rough or smooth, to act upon the particles of a water-sorted product. The smaller grains, of high specific gravity, are moved down the slope slowly or not at all by the slow undercurrent; the larger grains, of lower specific gravity, are moved rapidly down the slope by the quick upper current. These tables may be classified as: Surface tables, from which the products are removed before they have formed a bed, so that the washing is always done on the same surface; and building tables or buddles, on which the products are removed after they have formed a bed.

Frue Vanner.—This consists essentially of a rubber belt traveling up a slight inclination. The material to be treated is washed by a constant flow of water while the entire belt is meanwhile shaken from side to side. Other vanners of the sideshake type are the Tulloch, Johnston and Norbom.

Gates Canvas Table.—A large form of inclined canvas table in which the pulp is first classified, then distributed along the upper edge of the table. The concentrates are caught in the warp of the canvas and after this is full, treatment must be

stopped while the concentrates are swept or sluiced off.

Gröndal.—A magnetic separator consisting of a vertical revolving cylinder made up of rings of cast iron with the spaces between containing the wires for the electric current. Each ring is so magnetized as to be a little stronger than the one above. There is another cylinder of wood studded with soft wrought-iron pegs, a ring of pegs being opposite each castiron ring. The magnetic portion of the ore (usually crushed below 12 mesh) is carried around on the cast-iron rings until it gets near the pegs, to which it jumps because of their induced magnetism. It is then carried on these pegs out of the magnetic field and thrown off.

Hallett Table.—This is like the WILFLEY except that the tops of the riffles are in the same plane as the cleaning planes and the riffles are sloped toward the wash-water side.

Hancock Jig.—A jig with movable sieve having both an up-and-down and a reciprocating motion.

Harz or Plain Eccentric Jig.—One in which pulsion is given intermittently with suction. The periods devoted to them are

about equal.

Huff Separator.—An electrostatic machine depending on the repelling and attracting action of electrically charged particles. The feed is passed over a roller, and the constituents take various electrical charges according to conductivity and are repelled This machine is superseding the old BLAKE type.

Isbell Table.—A table with a reciprocating motion in which there is no cross wash water. The bed of pulp is deep as in a jig, and heavy material goes to the bottom. The concentrates and tailings are then split by means of a cut-out which can be adjusted vertically to skim at any height desired. The riffles make an angle of about 20° with the line of motion of the table.

James Concentrator.—The table deck is divided into two sections, flexibly joined together on a line oblique to the line of motion of the table. One section is riffled for the coarse material while the other section is smooth, to allow the settling of the fine particles which will not settle on a riffled surface. By means of the joint, the slope of the sections can be varied independently.

Johnston Vanner.—The chief difference between this and a Frue (q.v.) is that the belt is given an undulating motion, designed to prevent sands from piling up against the edges of the

belt.

Kieves.—These are strong tubs with sides flaring upward, in which separation is effected by mechanical agitation in a deep mass of thick pulp. Stirring paddles are used for preliminary mixing, and hammers or heavy striking bars for the final separation. They are used to finish the concentration of fine products

that are nearly rich enough to ship.

Log Washer.—This is a slightly slanting trough in which revolves a thick shaft or log, carrying blades obliquely set to the axis. Ore is fed in at the lower end, water at the upper. The blades slowly convey the lumps of ore uphill against the current, while any adhering clay is gradually disintegrated and floated out the lower end.

Overstrom Table.—A WILFLEY squeezed out into a diamond

shape (rhomboid), thus eliminating the waste corners.

Pinder Concentrator.—A revolving table on which are tapering spiral copper cleats on a linoleum cover. The tailings are washed over the riffles and off the edge while the concentrates are delivered at the end of the riffles.

Richard's Pulsator Jig.—An outcome of the pulsator classifier,

in which a pulsating column of water is used in the jig.

Rittinger Table.—A side-bump table with plane surface, using

a cam, spring and bumping post.

Spitzlutte.—This is a classifying device consisting of a V-shaped box, as distinguished from the pyramidal boxes of the spitzkasten. Classification is dependent on the force of a stream of water admitted at the bottom.

Sutton, Steele and Steele Dry Table.—A concentrator of the Wilfley type in motion, but instead of using water, stratification is by means of rising currents of air. The heavy grains are pushed forward by the head motion, while the lighter grains roll or flow down the slope toward the tailing side.

Triumph Concentrator.—This machine resembles a Frue vanner (q.v.), but the shaking motion is endwise instead of side

to side.

Trough Washer.—This is used to float adhering clay or fine stuff from the coarser portions of an ore. In its simplest form it is a sloping wooden trough, 1½ to 2ft. wide, 8 to 12ft. long and 1 ft. deep, open at the tail end, but closed at the head end.

Ullrich Magnetic Separator.—These machines have powerful electromagnets of wedge section. The material is treated on rolls on which magnetism is induced. They consist of alternate

disks of soft iron and some non-magnetic material. The ore is fed over the first roll, which removes the most magnetic material, and the tailings go on to the second which is weaker, where a

second separation is made.

Vanner.—See Frue vanner for general description of the side-shake type. There is also an end-shake type, which includes the Triumph concentrator, Embry concentrator, and Woodbury vanner, and a gyrating type, the Ellis. A 4-ft. vanner may take up to 13 gal. of water per minute and the weight of water to dry sand may rise to 10.7:1. The pulp bed may be as much as 0.45 in. thick.

Wetherill's Magnetic Separator.—Parallel form. Two flat belts, the upper of which is the wider, run parallel to each other. The magnets are long and set obliquely to the belts. Consequently magnetic particles are drawn up against the upper belt, more diagonally out and as they pass beyond the influence of the magnets, fall from the edge past the other belt into a concentrates bin. Another form operates by belts moving across the line of travel of the main belt.

Wilfley Slimer.—A form of shaking canvas table which is

given a vanner motion.

Wilfley Table.—A side jerk table with a riffled surface. The light and heavy grains are separated into layers by agitation, and the jerking action then throws the heavy grains toward the head end, while the light grains are washed down over the cleats into the tailings box. The table tapers toward the head end, and the riffles are progressively longer toward the tailings side. The Dodd, Cammett, Hallett and Woodbury are very like it.

Woodbury Jig.—A jig with a plunger compartment at the head end, so that the material is given a classification in the

jig.

Woodbury Table.—A table of the general WILFLEY-OVER-STROM-CARD type, with the riffles parallel to the tailing side, and a hinged portion without riffles (unlike the Card). The table top is a rhomboid, and the riffles gradually shorten as they near the tailings side.

CONCENTRATING AND CYANIDING MACHINERY

The following list includes the most important types of concentrating and cyaniding machinery not already described under crushing and concentrating equipment.

Akins Classifier.—A classifier of the free-settling type, in which the heavy material is driven up an inclined plane by

means of an interrupted-flight screw conveyor.

Blaisdell Reclaiming Apparatus.—Apparatus for automatically discharging sand tank having a central bottom opening. Consists of a central vertical shaft carrying four arms fitted with round plow disks. Sand is plowed toward central opening and discharged on a conveyor belt.

Blaisdell Loading Machinery.—Apparatus for loading sand tanks. Consists of a rapidly revolving disk with curved radial

vanes. Disk is hung on a shaft in tank center. Sand dropped on disk is distributed over the entire tank area.

Brown Tank.—As ordinarily used it is a cylindrical tank 45 ft. high and 15 ft. in diameter, ending at the lower end in a 60° cone. Within the tank is a hollow column about 15 in. in diameter extending from about 18 in. of the bottom to within about 8 in. of the top. A 1½-in. air pipe discharges air upward at and into the tube. The apparatus works on the air-lift principle, the pulp in the tube being lightened by the air, flowing upward, and being discharged at the top, more pulp flowing in at the bottom to take its place.

Bunker Hill Screen.—A rotating screen shaped like a funnel. Material is delivered inside the funnel, undersize passing through the screen while the oversize is discharged through the

funnel neck.

Burt Filter.—This is a stationary, intermittent filter in which the leaves are suspended vertically in a round tank set on a considerable incline. The leaves are therefore ellipses. The slime cake is discharged by introducing air and water into the interior of the leaf. There is also a newer Burt filter of the continuous

rotating-drum type.

Butters Filter.—This is a stationary, intermittent vacuum filter. The leaves are arranged in a box having a pyramidal bottom. When the pulp is introduced a vacuum is applied until a cake from 1 to 2 in. in thickness is formed. The surplus solution is then removed from the box and wash solution or water introduced. After removing the wash solution, either the box is filled with water or the cake dropped and sluiced out.

Callow Screen.—A classifying screen using the travelingbelt principle, the screen cloth forming the belt member. It passes over two drums, or pulleys, oversize being discharged

while the belt travels under the drums.

Callow Cone.—This is a conical settling tank with vertical central feed, peripheral overflow, annular launder to collect and convey away the overflow, and a spigot in the form of a gooseneck to discharge the tailings.

CALLOW CONE TEST ON BUTTE COPPER SLIMES

	Total gal. per min.	Grams per gal.	Tons per 24 hr.	Assay per cent. Cu	Oz. Ag per ton
Feed	1792.7	41.15	117.16	2.80	2.81
	1495.0	16.25	38.45	1.815	2.36
	297.5	154.5	73.13	3.5	3.34

Dehne Filter Press.—One of the best known of the standard plate-and-frame presses, which see.

Dorr Agitator.—An agitating machine based on the thickener

principle. It is essentially a Dorr thickener equipped with a central air-lift.

Dorr Classifier.—A machine to diminish the amount of water required for classification by raking the heavier grains up an inclined plane against a light current of water, which washes away the lighter material. It is of the intermittent type.

Esperanza Classifier.—A classifier of the free-settling type in which the settled material is removed by dragging it up an inclined plane by means of a continuous belt of flat blades or paddles. This is continuous in its operation.

France Screen.—A traveling belt screen in which the screencloth is mounted on a series of separate pallets, thus avoiding

bending the screen as it goes over the pulleys.

Hunt Continuous Filter.—A horizontally revolving continuous vacuum filter. It consists of an annular filter bed, usually of triangular wooden slats filled with coarse sands. The vacuum withdraws part of the pulp moisture as soon as the bed is formed. A spray then washes it after which the vacuum dries it and the material is then scraped off.

Impact Screen.—A type in which the screen moves with the load of material, bringing up against a stop so as to throw the material forward on it. The Imperial is probably the best

known type.

Imperial Screen.—A pulsating screen in which the ore is thrown up in the air as well as moved forward over the screen.

Kelly Filter.—This is an intermittent, movable pressure filter. The leaves are vertical and are set parallel to the axis of the tank. Pulp is introduced into the tank (a boiler-like affair) under pressure and the cake formed. The head then is unlocked and the leaves run out of the tank chamber, by means of a small track, and the cake is dropped. The carriage and leaves are then run back into the tank and the cycle begun again.

King Screen.—A drum-type screen in which the pulp to be screened is delivered on the outside, the undersize passing through the screen and discharging through the open end.

Maxton Screen.—A screening machine of the trommel class, open at each end and rotating on rollers supporting the tube through tires at each end. There are radial elevating ribs, to prevent wear of screen cloth and to elevate the oversize. Unscreened material is delivered on the inside screen surface, undersize passing through and oversize being elevated and discharged into a separate launder.

Merrill Filter Press.—A variation of the plate-and-frame

press.

Moore Filter Press.—The best known of the movable, intermittent vacuum filters. A series, "or basket," of leaves is fastened together in such a way that it may be dropped in a pulp tank and kept submerged until a cake is formed. It is then transferred by crane to an adjoining wash-solution tank and washed. The basket is then lifted out of this and the cake dropped.

Newaygo.—A slanting screen down which the material to be

screened passes. The screen is kept in vibration by the impact

of a vast number of small hammers.

Oliver Continuous Filter.—This consists of a revolving drum prepared as a leaf-filtering surface and divided into compartments, each of which is connected to a vacuum pipe and to a pipe for admitting compressed air. The drum is partly immersed in a tank or box of thick pulp and revolves at a slow rate of speed. The vacuum causes a 1/4 to 1/2-in. slime cake to form; after emerging, the solution is sucked out of the adhering cake; a wash is then given and displaced by air as far as possible; and finally the cake is dropped by compressed air.

Ovoca Classifier.—A classifier of the free-settling type in which the heavy material is removed by a double-screw, con-

tinuous-flight conveyor, working up an inclined plane.

Pachuca Tank.—Same as the Brown tank.

Paddle-wheel Agitator.—The simplest form, in which the solids are kept in suspension by paddles. It is difficult to do with sand, the machine being difficult (if not impossible) to start if sand packs around the blades, and it is expensive both in operating and in repair costs.

Parral Agitator.—An agitator using a number of small air lifts disposed about a circular, flat-bottomed tank in such a

way as to impart a circular swirling motion to the pulp.

Patterson Agitator.—An agitator of the Pachuca-tank type in which the air is replaced by solution or water, under pressure

from a centrifugal pump.

Plate-and-frame Filter Press.—The old style press. consists of plates with a girdiron surface alternating with hollow frames, all of which are held by means of lugs, on the press framework. The corners of both frames and plates are cored to make continuous passages for pulp and solution. The filter cloth is placed over the plates. The pulp passageway connects with the large square opening in the frame; the solution passageways with the girdiron surface of the plate. Dehne and the Merrill are well-known types.

Richard's Pulsator Classifier.—A classifier operating by a pulsating current of water without a screen. The pulp grains fall through a sorting column against an upward pulsating cur-

rent of water.

Ridgeway Filter.—This is a horizontal revolving, continous vacuum filter. The surface is an annular ring consisting of separate trays with vacuum and compressed air attachments. The filtering surface is on the under side, the trays being dipped into the tank of pulp to form the cake, and then lifted out of it.

Richard's Shallow-pocket Hindered-settling Classifier .-- A series of pockets through which successively weaker streams of water are directed upward. The material that can settle does

so and is drawn off through spigots.

Sherman Settler.—A series of cylindrical tanks with conical bottoms having central feed and a peripheral overflow. The tanks continually decrease in depth and increase in diameter.

Trent Agitator.—This agitator has the arms of the paddle-

wheel type, but they are hollow, and pulp solution or air is discharged from nozzles on these arms, thus causing the stirrer to rotate.

Trommel.—A revolving screen set at an angle. The material to be screened is delivered inside the trommel at one end. The fine material drops through the holes; the coarse is delivered at the other end.

Vibracone.—A vibrating screen manufactured by the Stephens-Adamson company, in which the feed is from a saucer-shaped distributor onto a conical surface kept in vibration by a ratchet motion.

POWER USED IN BOSTON & MONTANA CONCENTRATOR

Machine	R.p.m.	Horsepower required
Hancock jig	62	3.41
Evans jig	1	0.50
Trommel (3×6-ft.)		0.30
Overstrom table	251	0.364
Wilfley table	251	0.352
Vanner (4-ft.)	182	0.230

Power Used in Concentrating Mills

As an indication of what power may be needed in milling, the following table is taken from R. H. RICHARD'S "Ore Dressing," Vol. IV, page 1929. The figures are those for the Cananea Consolidated Copper Co.'s No. 2 and No. 1 mills:

	Horsepower
20 trommels 4×5 ft. and 4×8 ft	
4 16-in. elevators, 46 ft. between pulley cer	ters 10
4 sets 16×36-in. rolls at 80 r.p.m	20
6 one-compartment hull jigs (4 active)	8
16 two-compartment middle jigs	16
16 three-compartment sand jigs	16
2 dewatering trommels	1
2 chip trommels.	
10 shovel wheels with shefting	
10 shovel wheels with shafting	
2 centrifugal pumps, 1200 gal. per minute,	40-ft. lift 60
8 5-ft. Bryan mills	144
38 Wilfley tables with line shafting	
36 6-ft. Frue vanners with line shafting	8
2 centrifugal pumps	
6 shaking launders	3
2 middling elevators	5
2 pulp elevators	
2 pulp elevators Friction of engine and remaining shaftin	g 80
Trionon of cusine and temaning againm	5
Total on mill anging	472
Total on mill engine	***************************************
1400 tons of ore treated per day.	

	Horsepower
24 trommels	
2 No. 1 elevators	13
2 No. 2 elevators	
2 No. 3 elevators	
2 No. 4 elevators	
8 bull-jigs (4 active)	
16 two-compartment jigs	16
8 three-compartment jigs	8
2 Bryan mills	36
2 No. 1 centrifugal pumps	40
2 shaking launders and 2 shovel wheels	2
2 16×36-in. Davis rolls	2 2
4 14×27-in. Davis rolls	
shafting and belts	
engine and jackshaft friction	50
engine and jackshare friction	
Total angine load	317
Total engine load	
42 Wilfley tables	
36 six-foot Frue vanners	
2 10×48-in. sand pumps	
1 No. 2 centrifugal pump	
Friction of transmission	10
Total motor driven land	- AK
Total motor-driven load	65
Total motor-driven load	65 382
Total power required in mill	65 382
Total power required in mill	382
Total power required in mill	382
Total power required in mill	382
Total power required in mill	382) ; 10 × 20,
Total power required in mill. 1400 tons of ore treated per day. Power Used in Mills (Data furnished by General Engineering Co Crushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1	.); 10 × 20, 5 h.p.
Total power required in mill	.); 10 × 20, 5 h.p. 3, 25 h.p.;
Total power required in mill. 1400 tons of ore treated per day. Power Used in Mills (Data furnished by General Engineering Co Crushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1 Gates.—D Style No. 1, 10 h.p.; No. 2, 15 h.p.; No. No. 4, 30 h.p.; No. 5, 40 h.p.; No. 6, 60 h.p.; No. 7	.); 10 × 20, 5 h.p. 3, 25 h.p.;
Total power required in mill. 1400 tons of ore treated per day. Power Used in Mills (Data furnished by General Engineering Co Crushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1 Gates.—D Style No. 1, 10 h.p.; No. 2, 15 h.p.; No. No. 4, 30 h.p.; No. 5, 40 h.p.; No. 6, 60 h.p.; No. 7, No. 8, 150 h.p.	.) ; 10 × 20, 5 h.p. 3, 25 h.p.; , 125 h.p.;
Total power required in mill. 1400 tons of ore treated per day. Power Used in Mills (Data furnished by General Engineering Co Crushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1 Gates.—D Style No. 1, 10 h.p.; No. 2, 15 h.p.; No. No. 4, 30 h.p.; No. 5, 40 h.p.; No. 6, 60 h.p.; No. 7, No. 8, 150 h.p. Mills.—10-stamp, 90 8-in. drops per min., 750 lbs	.) ; 10 × 20, 5 h.p. 3, 25 h.p.; , 125 h.p.;
Total power required in mill	.) ; 10 × 20, 5 h.p. 3, 25 h.p.; 125 h.p.; s., 15 h.p.;
Total power required in mill	.) ; 10 × 20, 5 h.p. 3, 25 h.p.; 125 h.p.; s., 15 h.p.;
Total power required in mill. 1400 tons of ore treated per day. Power Used in Mills (Data furnished by General Engineering Co Crushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1 Gates.—D Style No. 1, 10 h.p.; No. 2, 15 h.p.; No. No. 4, 30 h.p.; No. 5, 40 h.p.; No. 6, 60 h.p.; No. 7, No. 8, 150 h.p. Mills.—10-stamp, 90 8-in. drops per min., 750 lbs 850-lb., 17 h.p.; 950-lb., 19 h.p.; 1000-lb., 20 h.p. Tubes.—5 × 14-ft., 30 h.p.; 5 × 22-ft., 70 h.p.; 450 h.p.	.) ; 10 × 20, 5 h.p. 3, 25 h.p.; 125 h.p.; s., 15 h.p.;
Total power required in mill	382 .) ; 10 × 20, 5 h.p. 3, 25 h.p.; 125 h.p.; s., 15 h.p.; 4 × 20-ft.,
Total power required in mill	382 382 5 h.p.; 3, 25 h.p.; 125 h.p.; 3., 15 h.p.; 4 × 20-ft.,
Total power required in mill	382 382 5 h.p.; 3, 25 h.p.; 125 h.p.; 3., 15 h.p.; 4 × 20-ft.,
Total power required in mill	382 382 5 h.p.; 3, 25 h.p.; 125 h.p.; 3., 15 h.p.; 4 × 20-ft.,
Total power required in mill	382 382 5 h.p.; 3, 25 h.p.; 125 h.p.; 3., 15 h.p.; 4 × 20-ft.,
Total power required in mill. 1400 tons of ore treated per day. Power Used in Mills (Data furnished by General Engineering Cocushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1 Gates.—D Style No. 1, 10 h.p.; No. 2, 15 h.p.; No. No. 4, 30 h.p.; No. 5, 40 h.p.; No. 6, 60 h.p.; No. 7 No. 8, 150 h.p. Mills.—10-stamp, 90 8-in. drops per min., 750 lbs 850-lb., 17 h.p.; 950-lb., 19 h.p.; 1000-lb., 20 h.p. Tubes.—5 × 14-ft., 30 h.p.; 5 × 22-ft., 70 h.p.; 4 50 h.p. Chilian.—4-ft., 6 h.p.; 5-ft., 12 h.p.; 6-ft., 25 h.p. Huntington.—3½-ft., 4-5 h.p.; 5 ft., 6-7 h.p.; 6-ft., Rolls. Cornish.—12 × 20, 12 h.p.; 14 × 27, 16 h.p. 25 h.p. Sample Grinders.—No. 1, 3 h.p.; No. 2, 4 h.p. Amalgamating Pans.—5-ft., 4 h.p.; 8-ft., 6 h.p.	382 382 5 h.p.; 3, 25 h.p.; 125 h.p.; 3., 15 h.p.; 4 × 20-ft.,
Total power required in mill. 1400 tons of ore treated per day. Power Used in Mills (Data furnished by General Engineering Cocushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1 Gates.—D Style No. 1, 10 h.p.; No. 2, 15 h.p.; No. No. 4, 30 h.p.; No. 5, 40 h.p.; No. 6, 60 h.p.; No. 7 No. 8, 150 h.p. Mills.—10-stamp, 90 8-in. drops per min., 750 lbs 850-lb., 17 h.p.; 950-lb., 19 h.p.; 1000-lb., 20 h.p. Tubes.—5 × 14-ft., 30 h.p.; 5 × 22-ft., 70 h.p.; 4 50 h.p. Chilian.—4-ft., 6 h.p.; 5-ft., 12 h.p.; 6-ft., 25 h.p. Huntington.—3½-ft., 4-5 h.p.; 5 ft., 6-7 h.p.; 6-ft., Rolls. Cornish.—12 × 20, 12 h.p.; 14 × 27, 16 h.p. 25 h.p. Sample Grinders.—No. 1, 3 h.p.; No. 2, 4 h.p. Amalgamating Pans.—5-ft., 4 h.p.; 8-ft., 6 h.p. Grinding Pans.—5-ft., 6 h.p.; 8-ft., 9 h.p.	382 382 5 h.p.; 3, 25 h.p.; 125 h.p.; 3., 15 h.p.; 4 × 20-ft.,
Total power required in mill	382 382 5 h.p.; 3, 25 h.p.; 125 h.p.; 3., 15 h.p.; 4 × 20-ft.,
Total power required in mill. 1400 tons of ore treated per day. Power Used in Mills (Data furnished by General Engineering Co Crushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1 Gates.—D Style No. 1, 10 h.p.; No. 2, 15 h.p.; No. No. 4, 30 h.p.; No. 5, 40 h.p.; No. 6, 60 h.p.; No. 7 No. 8, 150 h.p. Mills.—10-stamp, 90 8-in. drops per min., 750 lbs 850-lb., 17 h.p.; 950-lb., 19 h.p.; 1000-lb., 20 h.p. Tubes.—5 × 14-ft., 30 h.p.; 5 × 22-ft., 70 h.p.; 4 50 h.p. Chilian.—4-ft., 6 h.p.; 5-ft., 12 h.p.; 6-ft., 25 h.p. Huntington.—3½-ft., 4-5 h.p.; 5 ft., 6-7 h.p.; 6-ft., Rolls. Cornish.—12 × 20, 12 h.p.; 14 × 27, 16 h.p. 25 h.p. Sample Grinders.—No. 1, 3 h.p.; No. 2, 4 h.p. Amalgamating Pans.—5-ft., 4 h.p.; 8-ft., 6 h.p. Grinding Pans.—5-ft., 6 h.p.; 8-ft., 9 h.p. Settlers.—8-ft., 3 h.p. Agitators.—8-ft., 3 h.p. Clean-up Pans.—48-in., 1½ h.p.	382 382 5 h.p.; 3, 25 h.p.; 125 h.p.; 3., 15 h.p.; 4 × 20-ft.,
Power Used in Mills (Data furnished by General Engineering Co Crushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1 Gates.—D Style No. 1, 10 h.p.; No. 2, 15 h.p.; No. No. 4, 30 h.p.; No. 5, 40 h.p.; No. 6, 60 h.p.; No. 7 No. 8, 150 h.p. Mills.—10-stamp, 90 8-in. drops per min., 750 lbs 850-lb., 17 h.p.; 950-lb., 19 h.p.; 1000-lb., 20 h.p. Tubes.—5 × 14-ft., 30 h.p.; 5 × 22-ft., 70 h.p.; 50 h.p. Chilian.—4-ft., 6 h.p.; 5-ft., 12 h.p.; 6-ft., 25 h.p. Huntington.—3½-ft., 4-5 h.p.; 5 ft., 6-7 h.p.; 6-ft., Rolls. Cornish.—12 × 20, 12 h.p.; 14 × 27, 16 h.p. 25 h.p. Sample Grinders.—No. 1, 3 h.p.; No. 2, 4 h.p. Amalgamating Pans.—5-ft., 4 h.p.; 8-ft., 6 h.p. Grinding Pans.—5-ft., 6 h.p.; 8-ft., 9 h.p. Settlers.—8-ft., 3 h.p. Agitators.—8-ft., 3 h.p. Clean-up Pans.—48-in., 1½ h.p. Hendryx Agitator.—5 h.p.	382 .) ; 10 × 20, 5 h.p. 3, 25 h.p.; 125 h.p.; 4 × 20-ft., 8-10 h.p. ; 16 × 36,
Power Used in Mills (Data furnished by General Engineering Co Crushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1 Gates.—D Style No. 1, 10 h.p.; No. 2, 15 h.p.; No. No. 4, 30 h.p.; No. 5, 40 h.p.; No. 6, 60 h.p.; No. 7 No. 8, 150 h.p. Mills.—10-stamp, 90 8-in. drops per min., 750 lbs 850-lb., 17 h.p.; 950-lb., 19 h.p.; 1000-lb., 20 h.p. Tubes.—5 × 14-ft., 30 h.p.; 5 × 22-ft., 70 h.p.; 6 h.p. Chilian.—4-ft., 6 h.p.; 5-ft., 12 h.p.; 6-ft., 25 h.p. Huntington.—3½-ft., 4-5 h.p.; 5 ft., 6-7 h.p.; 6-ft., Rolls. Cornish.—12 × 20, 12 h.p.; 14 × 27, 16 h.p. 25 h.p. Sample Grinders.—No. 1, 3 h.p.; No. 2, 4 h.p. Amalgamating Pans.—5-ft., 4 h.p.; 8-ft., 6 h.p. Grinding Pans.—5-ft., 6 h.p.; 8-ft., 9 h.p. Settlers.—8-ft., 3 h.p. Agitators.—8-ft., 3 h.p. Clean-up Pans.—48-in., 1½ h.p. Hendryx Agitator.—5 h.p. Revolving Screens.—½ h.p. Revolving Dryers.—	382 .) ; 10 × 20, 5 h.p. 3, 25 h.p.; 125 h.p.; 4 × 20-ft., 8-10 h.p. ; 16 × 36,
Total power required in mill. 1400 tons of ore treated per day. Power Used in Mills (Data furnished by General Engineering Co Crushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1 Gates.—D Style No. 1, 10 h.p.; No. 2, 15 h.p.; No. No. 4, 30 h.p.; No. 5, 40 h.p.; No. 6, 60 h.p.; No. 7 No. 8, 150 h.p. Mills.—10-stamp, 90 8-in. drops per min., 750 lbs 850-lb., 17 h.p.; 950-lb., 19 h.p.; 1000-lb., 20 h.p. Tubes.—5 × 14-ft., 30 h.p.; 5 × 22-ft., 70 h.p.; 4 50 h.p. Chilian.—4-ft., 6 h.p.; 5-ft., 12 h.p.; 6-ft., 25 h.p. Huntington.—3½-ft., 4-5 h.p.; 5 ft., 6-7 h.p.; 6-ft. Rolls. Cornish.—12 × 20, 12 h.p.; 14 × 27, 16 h.p. 25 h.p. Sample Grinders.—No. 1, 3 h.p.; No. 2, 4 h.p. Amalgamating Pans.—5-ft., 4 h.p.; 8-ft., 6 h.p. Grinding Pans.—5-ft., 6 h.p.; 8-ft., 9 h.p. Settlers.—8-ft., 3 h.p. Agitators.—8-ft., 3 h.p. Clean-up Pans.—48-in., 1½ h.p. Hendryx Agitator.—5 h.p. Revolving Screens.—½ h.p. Revolving Dryers.—Wilfley Tables.—¾ h.p. Frue Vanners.—½ h.p.	382 .) ; 10 × 20, 5 h.p. 3, 25 h.p.; 125 h.p.; 4 × 20-ft., 8-10 h.p. ; 16 × 36,
Power Used in Mills (Data furnished by General Engineering Co Crushers. Blake.—7 × 10, 8 h.p.; 9 × 15, 15 h.p. 20 h.p.; 15 × 24, 30 h.p. Dodge.—4 × 6, 2 h.p.; 7 × 10, 7 h.p.; 11 × 15, 1 Gates.—D Style No. 1, 10 h.p.; No. 2, 15 h.p.; No. No. 4, 30 h.p.; No. 5, 40 h.p.; No. 6, 60 h.p.; No. 7 No. 8, 150 h.p. Mills.—10-stamp, 90 8-in. drops per min., 750 lbs 850-lb., 17 h.p.; 950-lb., 19 h.p.; 1000-lb., 20 h.p. Tubes.—5 × 14-ft., 30 h.p.; 5 × 22-ft., 70 h.p.; 6 h.p. Chilian.—4-ft., 6 h.p.; 5-ft., 12 h.p.; 6-ft., 25 h.p. Huntington.—3½-ft., 4-5 h.p.; 5 ft., 6-7 h.p.; 6-ft., Rolls. Cornish.—12 × 20, 12 h.p.; 14 × 27, 16 h.p. 25 h.p. Sample Grinders.—No. 1, 3 h.p.; No. 2, 4 h.p. Amalgamating Pans.—5-ft., 4 h.p.; 8-ft., 6 h.p. Grinding Pans.—5-ft., 6 h.p.; 8-ft., 9 h.p. Settlers.—8-ft., 3 h.p. Agitators.—8-ft., 3 h.p. Clean-up Pans.—48-in., 1½ h.p. Hendryx Agitator.—5 h.p. Revolving Screens.—½ h.p. Revolving Dryers.—	382 .) ; 10 × 20, 5 h.p. 3, 25 h.p.; 125 h.p.; 4 × 20-ft., 8-10 h.p. ; 16 × 36,

WATER USED IN MILLS!

Strategies Str	Mill	Water used per 24 hr., gal.	Capacity of mill per 24 hr., tons	Water used per ton, gal. (c)	Remarks, stamps
COMBINATION SILVER MILLS Steam power 15,360(b) 120 457 0 457 0 457 0 457 0 457 0 457 0 457 0 457 0 457 0 469 umped 30,000 1,000 0 1,000			MP Mills 90 80 80 80 80 80 80 80 80 80 80 80 80 80		855358888888
Steam power 15,360(b) 120 2,296.1 457 0 100,000 1,000.0 1,00			ILS.		
(Fresh 70,000 1,000.0 1		22	110	2,296.1 457 0	60
JIGGING MILLS 62,000(c) 120 to 135 459.8 to 516 7	:	70,000 30,000 100,000	100	1,000.0	3
62,000(e) 120 to 135 459.8 to 516 7		JIGGING MILLS			
		62,000(c)	120 to 185		

MILLS WITH JIGS, VANNERS AND TABLES

Mill	Water used per 24 hr., gal.	Capacity of mill per 24 hr., tons	Water used per ton, gal. (c)	Remarks, stampe
Old Jurdan & Galena, Bugham, Utah Central Lead, Flat River, Mo 3t Joseph Lead Co, Bonne Terre, Mo Bullon Beck & Champion, Eureks, Utah. Smuggler, Aspen, Colo	237,600 1,152,000 2,250,000 129,600 900,000(a) (e)	175 175 100 100	1,367.6 6,582.8 2,500.0 648.0 9,000.0	
	MONTANA COPPER SULPRIDE	Mills		
Butte & Boston, Butte, Mont	Flows in 1,000,000 Pumped 1,440,000 Repumped 700,000	909	2,000 2,880 1,400	
Colo. Sm. & Ref., Butte, Mont Parrot Silver & Copper, Butte, Mont	3,140,000 1,064,000 1,200,000 to 1,400,000	275 to 300 300 to 350	3,546 7 to 3,869 0 4,000	
LAKE SUPERIOR	NATIVE COPPER MILLS W	WITH STEAM STAMPS	AMPS	
Calumet & Heela, Calumet, Moat Franklin, Hancock, Mich Osceoln, Mich Quincy, Hancock, Mich Tamarack, Houghton, Mich	20,000,000 3,744,000(d) 12,000,000 12,000,000 10,000,000	2,080 450 1,260 1,700 to 1,900 1,500	9,615.4 8,320 0 9,523.8 6,315.8 to 7,058 8	
(a) The mill is run by water power, and this figure does not include the water used for power. (b) This does not include what is repumped. (c) This is for 10 hours only. (d) This is the water that leaves the mill with the tailings. The amount of water	this figure does not include the way, (d) This is the water that leaves	er used for power the mill with the	tailings. The amor	nclude what

For all that, coming to the mill is slightly larger.

The table is from Rickand's "Ore Dressing," Vol. II, and consequently represents the practice of 15 years ago. It is a valuable guide to have as to what water may be necessary.

WATER CONSUMPTION IN VARIOUS MILLS

·	Gal. water per 24 hr.	Tons ore per	Water per ton		Remarks
		24 hr.	Gallons	Tons	
	Gold	STAMP	Mills	3	
Haile, South Carolina	360,000	150	2,400	10	60 stamps
	Jigging	Mills			
Smuggler Mining Co St. Joe Lead St. Louis Sm. & Ref Block 10 Daly-West Minas Tecolotes Silver Lake	$2,160,000\\4,000,000\\5,760,000\\864,000^1\\69,000\\504,000^1\\57,600\\2,001,600^1\\338,400\\1,885,000$	400 1,200 1,800 } 575 \$ 500 600 325	5,400 3,333 3,200 { 1,500 ¹ 120 1,008 ¹ 144 { 3,336 ¹ 567 5,800	22.5 13.9 13.3 6.26 0.5 4.2 0.6 13.9 2.36 24.2	Australian
	lron Ore	Washe	ERY ⁴		
Oliver Iron Longdale Iron	300,000 ² 1,144,800	1,000 ² 480	300 2,385	1.25 10.0	
Monta	NA COPPER	SULPE	HDE MI	LLS	
Anaconda Boston & Montana	44,352,000 25,000,000	8,800 3,000	5,040 8,300	21.0 34.6	
U	ТАН СОРРЕ	r Sulp	HIDE	•	
Newhouse M. & S Utah Copper Co	$\left\{\begin{array}{c} 1,440,000^{1} \\ 720,000 \\ 8,640,000 \end{array}\right.$	} 1,000 6,000	{ 1,440¹ 720 1,440	6.0 3.0 6.0	}
Nı	EVADA COPP	er Sui	PHIDE	<u></u>	
Giroux Con	800,000 ¹ 160,000	} 800	{ 1,000¹ 200	4.01 0.83	
-	Arizona	Сорре	R	·	
Detroit Copper Min. Co. Old Dominion	275,000 750,000	1,100 500	250 1,500	1.04 6.26	
¹ In mill circulation.	² Ten hours.	* Accor	ding to R	ICHARD	s. the water

¹ In mill circulation. ² Ten hours. ³ According to RICHARDS, the water used in stamping varies from 1 to 6.69 gal. per stamp per minute in the various mills under his observation, and 2.40 to 15.97 tons per ton of ore stamped. South African practice seems to be about 4 to 10 tons of water per ton of ore milled. ⁴ Log washers take about 2000 gal. of water per ton of ore in Southern practice.

ADJUSTMENT, FEED AND CAPACITY OF MILL VANNERS

	Tons treated	by one vanner in 24 hours	•		4-6-6-6			•	• •		• • •			•	
reens	Feed	Maxi- mum size (a'), mm.						:	• •					•	
square holes in stamp screens	Fe	Source	93	EE:	SGE	(9)	(w)	(S)	<u> </u>	SE	E	(a) or (a) (o)	<u>\$</u>	<u> </u>	<u>;</u>
e holes in	Num- ber of	vibra- tions per minute	205–210	190	196 116	230	230	230	200	200 190 190	215		190-194	186	204
ı	Travel of belt	inches per minute	65}\$		24-36		80 76	80	26	36	(d')24		35-41	46	36-48
stamp screens; Sq.	Slope	Degrees	2°25′-2°50′	20 0/			0° 35′ 0° 45′		-	1° 12′	0° 35′			0 0 30 30 30	
ü	IS	Inches in 12 ft.	812-9	- 10	:0100	6.4	1135	∞ ∞ 4.∞	•	က	11/2		•	4.14 8.8	•
round holes	•	Life in months		24-36	24-60	•	•	•	• • •		48		54-60	•	90
. 1	Belt	Width, feet	4.4	1	400	2	rð	2	4	4 & 6	44	h 41	6 4	4	4
ns.—In. = inches; R.	B	Kind	Frue (k)	Frue	r rue Blaisdell	Woodbury	Woodbury	Woodbury	(b')Blaisdell (b')	දිදි	(4)	<u>ે</u>	Frue		(9)
Abbreviations.—In.		Kind of vanner	Frue	Frue	Frue Frue Johnston	Woodbury (g')	Woodbury (g')	Woodbury (g')	Frue	Frue	Frue	Frue	Frue	Frue	Frue .
	aber.	ava lliM	18	283	7 7 7 7		27		310	3 %	8. 70.	88	38,34		40

•	•	7.7%	163%	8.4 8.4 8.4	4	ស	3%	414	15	735-1035	ī	7%	1235	4.4	4	12	121%
	•	0.70 Sq.	:	1.10 Sq.	0.79 R.	0.59 Sq.	0.64 R.	:	0.81 R.	0.75 R.		•	0.76 R.	0.52 Sq.		•	0.76 R.
E	(V)(N)(M)	(a)	96	<u> </u>	(a)	(g)	(a)	(a)	(a)	(a)	(g)	(a)	(a)	88	g (g	(a) (d)	(8)
:	200	160	200	007	230 \ 200 \	200 238 238	200	:	225	206	180	730 730	168	196	216	7 7 7 7 7 7	175–185
•	36-72	4 4 8 8	-	08 	2 4 28	28 42-46	5 0	45 60	72	4.4 8.00	31	36-72 36-48	30.6 36.	22	55	200	32-35
	1° 25′	0 0	10 35/	•	1° 12′ 0° 54′	0°55′-1°5′ 2° 5′	1° 12′	1° 30′ 2° 20′	3° 30′	1° 30′ 2° 10′	(12)	1°12′-2°0′ 1°0′	20 20 32 32 32	1° 25′	10 20/		1° 47′-2° 5′
:	3,15	315	च	o 4 ′	\\ 3\\\ 23\\\	2.3-234	က	{ 33% 576	&. &.		534	27.2	572	3,6	335 4 2	335	415-514
48		\ .			્ર	120	36	30	30			4 4					72
4 10 4	44	410	∞ €	4	44	4173	4	4	ro	410	41	44	ক ক	4,€	4	10	44
(Canvas Rubber	(4)	Frue		Smooth surface	Blaisdell (c') Blaisdell (c')	Frue Blaisdell (c')	Brownell Woodbury	Blaisdell (c') Blaisdell (c') Woodbury	Woodbury	Blaisdell (b') Blaisdell (b')		<u> </u>	Blaisdell (b')		Frue	Woodbury	Frue Brownell Blaisdell
		(•													5	
Frue Tulloch	(Embrey Frue	$\begin{cases} Frue \\ Woodburv (a') \end{cases}$	Frue	Frue	Triumph Frue	Frue Triumph	Triumph	Frue	$\left\{\begin{array}{l} Woodbury (g') \\ Woodbury (h') \end{array}\right\}$	Frue Triumph	Frue	Frue Triumph	Frue	Frue	Frue	Woodbury (g')	Frue
41	43	23	2	55	22	8	59	90	61	62	63	49	65	80	22	73	73

	Tons treated	by one vanner in 24 hours	1235 935 735-1235 10 10 1235 536-6
	Feed	Maximum sise (a') , mm.	0.76 R. 1.13 Sq. 0.52 Sq. 0.42 Sq. 0.41 Sq. 0.41 Sq.
	Fe	Source	
	Num- ber of		150 } 188 224-240 20
	Travel of helt	inches per minute	55 38 37–42 85 85 24–36 20–30 35 18
	Slope	Degrees	2° 35' 2° 5' 1° 47' 7° 7' 1° 12' 1° 12' 1° 35' 1° 12' 1° 12' 1° 35' 1° 40'
	02	Inches in 12 ft.	63/4 49/4 33 33 44.2
	,	Life in months	09
	±	Width, feet	319 ₁₂ 44 66 66 66 67 67
,	Belt	Kind	Blaisdell (c') Blaisdell (c') (b') (b') (b') Woodbury Frue Blaisdell (b') Blaisdell (b') Blaisdell (b') Blaisdell (b') Woodbury Woodbury
		Kind of vanner	{ Tulloch Frue Frue Gates Woodbury Frue Frue Frue Frue Frue Frue Frue Frue
	per	ana lliM	74 776 778 887 887 888 888 888

As the screens wear The mill numbers refer to this bool surface current class hydraulic classifier 1 From R. H. RICHARD'S "Ore Dressing." with slime-table Second spigot of

Ft. In. Ft. In. In. per ft. Degrees OS 24 In. In. per ft. Degrees OS 24 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. Degrees OS 25 In. In. per ft. In		Length	gth	ριΜ	ridth	edog	8		p	Destination of	tion of	Tons treated
3 0 (v) 4 8 234 10° 35' (a) (f) (f) 7.5 10° 35' 10° 35' (b) 12 months (a) (f) (f) 7.5 10 112 0 113 0 1	King of table	Ft.	In.	봅	Ip.	In. per ft.	Degrees	LARG OF PAITINGS	1980	-πee l	Tagi in the	per table in
16 0 (v) 4 8 (h) 2 9° 30′ 12 months (a) (c) (7) 7.5 10 0 12 0 12 months (b) (m) (c) 12 0 12 0 12 months (c) (m) (c) 12 0 12 0 12 0 12 0 12 0 12 0 12 0 12	Brussels carpet	60	00	г -	000	23%		:	©	(3)	E	10-15
3 6 1 8 2 9° 30′ 12 months (a) (b) (7) 10 0 12 0 11½ 7° 5′ 8 months (b) (m) (c) 11½ 11½ 5° 20′ 8 months (c) (m) (c) 11½ 11½ 5° 20′ 8 months (c) (m) (c) 11½ 3° 20′ 8 months (d) (m) (d) 11½ 3° 20′ 10 months (d) (m) (d) (m) (d) (d) (d) (d) (d) (d) (d) (d) (d) (d	Janyaela carpet.	3 9	00	_		(g) 1/2 2/2 2/2 2/2 2/2 2/2 2/2 2/2 2/2 2/2			99	9	3	7.5-12.5
10 0 12 0 144 7° 5′ 8 months (b) (m) (c) 10 0 12 0 144 5° 20′ 8 months (c) (m) (d) (m) 10 0 12 0 144 5° 20′ 8 months (d) (m) (d) (m) (d) 10 12 0 144 8 145 5° 20′ 10 months (d) (m) (m) (m) (m) (m) (m) (m) (m) (m) (m	Vool blanket.	က	ф			63		12 months	ē	3	E	553
10 0 12 0 1 1 8	No. 6 cotton duck	10	0	12	0	11/2			3	Ē	3	1 25
10 0 12 0 (m) (s) (s) 13 3 20, 8 months (d) (m) (s) 1 16 6 1 8 3 25, 3 25, (10 months (g) (m) (s) (s) 1 42 0 1 8 13 5 20, 10 months (g) (e) (f) (f) (f)	No. 6 cotton duck	2	•	12	0	11/8			<u></u>	Œ.	<u></u>	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	No. 6 cotton duck	유	0	15	0				ુ	€.	E .	
15 6 1 8 138 5° 20' 10 months (g) (n) (t) 42 0 1 8 138 5° 20' 10 months (g) (o) (t) 4	Vo. 4 cotton duck	8	\$	-	90 6	270	3,30		<u>e</u>	<u> </u>	® (1.9
	No. 4 cotton duck	54	00		00 00	17.8	20,20	10 months	5 9	E S	99	4.55

Water Used in Jigging

According to RICHARDS, a jig will use anywhere from 0.528 to 22.22 gal. of water per square foot of jig area per minute, and from 8.76 to 54.98 tons of water per ton of ore in American practice, and 1.23 to 33.04 tons of water per ton of ore in European practice. The stroke of a jig varies from 1.63 to 7.18 times the diameter of the average grain fed to it. The coarser the grains the greater should be the throw, because coarse grains settle faster than fine grains and require a higher velocity of current and a greater quantity of water to lift them. The heavier the grains, the greater should be the stroke.

Water Required in Milling

(Data furnished by General Engineering Co.)

Classifiers. Hydraulic.—10-50 tons of water per ton of pulp. Jigs.—18 × 36-in. compartment HARZ jigs, per compartment, 1½-2½ mm. particles, 2-4 gal. per min.; 3½-5 mm. particles, 5-7 gal. per min.; 7-10 mm., 8-14 gal.; 15-20 mm., 21-28 gal. per min. This is in addition to the water in the feed.

Mills. Chile and Huntington.—Crushing to 20 mesh, 5-6

tons of water per ton of ore passing the screens.

Screens. Callow.—24-in. duplex. Water in pulp, 3½-4 tons of water per ton of feed; spray water undersize, 6-10 gal. per min.; oversize, 8-12 gal. per min.

Stamps.—800-1000 lb. stamps, 3-6 gal. per min.

Trommels.—36 \times 72-in., $1\frac{1}{2}$ – $3\frac{1}{2}$ mm. holes, 15–25 gal. per min.; $3\frac{1}{2}$ –7 mm. holes, 10–15 gal. per min.; 7–15 gal. per min., 5–8 gal. per min.

Vanners.—6 ft., $1\frac{1}{2}$ -3 gal. per min. Wilfley Tables.—5-10 gal. per min.

CARKEEK'S SLOPE FOR LAUNDERS1

Size of ore	Degrees	Slopes, inches per foot	
Mine ore to breaker	36° 35′	8.9	Dry.
2 in. to 1 in	37° 50′	9.33	Wet.
1 in. to ½ in	33° 40′	8.0	Wet.
$\frac{1}{2}$ in to $\frac{1}{4}$ in	29° 5′	6.66	Wet.
$\frac{1}{4}$ in. to $\frac{1}{8}$ in	24° 0′	5.33	Wet.
$\frac{1}{8}$ in. to $\frac{1}{16}$ in	18° 25′	4.0	Wet.
in. to vanner material	7° 33′	1.6	Wet.
Table or vanner material	6° 20′	1.33	Wet.
Tail race for 1/6-in. material	3° 35′	0.75	Wet.
Tail race for 1/8-in. or larger	6° 20′		Wet.
Frommel casing for $-\frac{1}{2}$ -in. material	16° 15′	3.5	Wet.
Trommel casing for $+\frac{1}{2}$ -in. material	33° 40′	8.0	Wet.

¹ R. H. RICHARDS, "Ore Dressing," Vol. II.

QUANTITIES OF WATER FLOWING IN RECTANGULAR LAUNDERS OF ROUGH PLANK

Depth of water			Slope in 1 fe		
in inches	1⁄8 in.	34 in.	32 in.	1 in.	2 in.
	GALI	LONS PER I	MINUTE, L	AUNDERS 4	In. Wide
$\frac{1}{2}$	5.8	8.2	11.7	16.5	23.3
	18.9	26.3	37.8	53.5	75.7
$egin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array}$	52.4	74.2	105.0	148.0	210.0
3	91.6	130.0	183.0	259.0	366.0
4	129.0	183.0	259.0	366.0	517.0
	LAT	INDERS 8	In. WIDE		·····
1	42.1	59.5	84.2	119	168
2 3 4 6 8	129.0	189.0	259.0	366	517
3	240.0	339.0	479.0	676	958
· 4	363.0	519.0	726.0	1,027	1,452
6	625.0	884.0	1,250.0	1,767	2,500
8	890.0	1,253.0	1,779.0	2,516	3,558
	Lau	NDERS 12	In. Wide	2	
1	69.3	98	139	196	277
2 4 6	211.0	298	422	597	844
4	625.0	884	1,250	1,767	2,500
	1099.0	1,554	2,198	3,108	4,396
9	1908.0	2,698	3,816	5,395	7,631
12	2736.0	3,868	5,471	7,736	10,943
	LAU	NDERS 16	In. Wide		·
1	94	133	188	266	376
2 4 8	309	437	617	873	1,235
4	890	1,258	1,779	2,516	3,559
	2,432	3,438	4,863	6,877	9,727
12	4,116	5,820	8,232	11,640	16,464
16	6,000	8,485	12,001	16,961	24,002
	LAU	NDERS 32	In. WIDE		<u> </u>
1	196	278	393	556	786
2	650	919	1,301	1,839	2,601
4	2,075	2,933	4,149	5,167	8,298
8	8,000	8,435	12,001	16,969	24,002
16	16,023	22,657	32,046	45,313	64,092
24	26,751	37,826	53,503	75,653	107,005
32	38,590	54,565	77,179	109,131	154,358

Water per Ton of Ore in Various Kinds of Mills

Stamps and Vanners.—20-30 mesh, 4-6 tons. Coarse Concentration.—Rolls, jigs and tables, 15-20 tons.

Combination Mills.—Stamps, vanners and pans, 6-8 tons. Cyanide Mills.—Shoveling tails and filter pressing, 0.2-0.35

Cyanide Mills.—Sluicing tailings, 1.3-1.9 tons.

SPEED OF CURRENT NECESSARY TO MOVE DIFFERENT SIZES OF SAND AND PEBBLES¹

		ttom of stream.
Material	Slowest observed velocity that moved the grains	Fastest observed velocity that did not move grains
Brown clay (sp. gr. 2.64)	0.62 1.07 0.53	0.27 0.53 0.71 0.36 0.62 1.07 2.13 3.20

Percentages of Moisture Retained by Different Sizes of ORE AFTER THOROUGH WETTING FOLLOWED BY REASON-ABLE DRAINING

Size, mm.	Material	Moisture, per cent.	Size, mm.	Material	Moisture, per cent. ²
64-32 32-22 22-16 16-12 12-8 8-6 6-4	Ore Ore Ore Calcite Ore Calcite Ore Calcite Calcite Calcite Calcite	2.91	4-3 3-2 2-1 1-0.5 0.5-0.35 0.35-0.10 0.10-0	Calcite Calcite Calcite Calcite Calcite Calcite Calcite Calcite Calcite Calcite Calcite Calcite Calcite	5.66 5.21 6.19 6.06 8.59 9.30 17.59 18.90 18.16 20.44 16.80 20.57 16.94 21.69

¹ R. H. RICHARDS, "Ore Dressing," Vol. II.
² Percentage calculated on weight of mixture of pulp and water.

Speed of Mineral Grains Falling in Water (Meters per SECOND)1

Diameter in mm.	Nature of grains	}% sec.	14 sec.	1/2 sec.	1 sec.	2 sec.
15	Galena	0.903	1.441	1.630	1.650	1.650
	Pyrites	0.825	1.174	1.287	1.293	1.293
	Quartz	0.570	0.767	0.801	0.817	0.817
4	Galena	0.704	0.814	0.823	0.824	0.824
	Pyrites	0.586	0.643	0.646	0.646	0.646
	Quartz	0.383	0.409	0.409	0.409	0.409
1	Galena	0.409	0.413	0.414	0.414	0.414
	Pyrites	0.321	0.323	0.323	0.323	0.323
	Quartz	0.203	0.204	0.204	0.204	0.204

SLOPE OF PLATES IN AUSTRALIAN MILLS?

Name of mill	Situation	Slope of plates, inches per foot	Water per battery per minute, gallons
New Star of the East Old Star of the East Britannia United Harrietville	Ovens dis-	7/8 3/4 1 7/8	37½ 37½ 25 25
Oriental	trict Ovens dis- trict	3/4	20
Old Fortuna New Fortuna Pearl New Chum Consolidated	Bendigo	15/16 11/8 13/4 11/4	321/2

The Flotation Process³

Everybody has, of course, noticed the dearth of discussion about the flotation process in the current technical literature. The explanation of this is the still unsettled patent litigation and the attitude of Minerals Separation, Ltd., the claimant. That company will neither permit its own employees to talk or write about the process, nor will it permit the employees of its licensees to do so. We do not recollect any metallurgical process of broad application and use respecting which such efforts toward secrecy have been exerted and so far have been successfully maintained. Toward that end no stone is left unturned. For example, a flotation apparatus is introduced

1." Handbook of Milling Details," McGraw-Hill Co.
2 R. H. RICHARDS, "Ore Dressing," Vol. II.
3 The Engineering and Mining Journal, Jan. 30, 1915.

somewhere for experimental purposes. The experiments finished, the apparatus, which is essentially a construction of timber, is destroyed with axes. Naturally those concerns which are employing the flotation process without license from Minerals Separation and are liable to be called into court, keep their mouths shut as a matter of policy.

This situation is likely to prevail until a final decision in the Hyde case is rendered by the Supreme Court of the United States. In the meanwhile the suit against the Miami Copper Co. has been taken under advisement and a decision is expected this Spring (1916). This suit brought into court review the

Callow and the Towne systems of flotation.

The flotation process as practised is a matter of delicate adjustment. With any given ore experiments may fail to give any promise whatever, simply because of failure to conform to some essential, and usually simple, condition. The size of the ore, the quantity of the feed, the temperature, etc., must all be just right, and especially must regularity of feed be attended to carefully. The fundamental features of the treatment also vary according to different ores. Thus, in floating the blende of Butte the addition of acid is necessary. In floating the copper ore of Miami the presence of acid is fatal. The character of the oil used also varies according to the ore. In the treat-ment of the zinc-lead ores of Broken Hill eucalyptus oil is commonly employed. In the treatment of the zinc ores of Butte, pine oil, a product of wood distillation (analogous to the eucalyptus oil of Australia) is generally used. Sometimes a little oleic acid is added. In the flotation of copper minerals heavier mineral oils are used. The choice seems to be more or less dependent upon what it is desired to accomplish. In the concentration of copper ore the aim is to extract all the copper possible and if considerable gangue is dragged out with it, no great harm is done. In the concentration of blende, however, the production of a high grade of concentrates is more important than the extraction of the maximum possible percentage of zinc. Therefore a lighter, more delicate oil is favored. In some processes of selective flotation some oils that are very light indeed are used. We have touched upon a few of the important points in connection with this process that ought to be discussed in technical literature, but probably that is not to be expected so long as the shadow of the litigation is over us.

Flotation Processes¹

Crilley and Everson.—The ore is crushed to 50 mesh, and mixed with a thick black oil. Boiling water containing enough acid to give it a tart taste is then added. This process was tried at Baker City, Ore., and at Denver, in 1889.

Robson and Crowder.—The ore was mixed with but little water, 25 to 30 per cent., agitated and oil added during agitation. This was operated at the Glasdir mine in Wales, in 1894.

¹ From Hoover's "Concentrating Ores by Flotation," "The Mining Magazine," London.

Elmore (Old Process).—The ore was mixed with several times its weight of water, and an equal, or greater weight of oil in a revolving drum. The oil was mixed without emulsifying, then run on a spitzkasten, where the oil carried the sulphides to the surface, and the gangue and water were removed from the This process was invented in 1898 and tried ex-

tensively. Its history may be said to close in 1905.

Potter-Delprat.—The original Potter process (1902) was one of flotation in a 1 to 10 per cent. acid solution. mixture was 1:1 of ore and acid solution; this was agitated freely and heat applied, causing the forming of CO2 from the carbonates in the ore. This caused the sulphides to rise to the surface where they were either allowed to flow off continuously or were skimmed off. This was clearly a surface tension process. DELPRAT (1902) accomplished the same thing with acid saltcake solution. Both processes were tried out at Broken Hill, Australia. Later patents indicate that oil has been found to assist in this process. These inventors worked independently, became involved in litigation and eventually pooled their

Froment.—Alcide Froment discovered in 1901 that when a sulphide ore is agitated in water with a little oil and sulphuric acid, the sulphide particles become oiled and attach themselves to and are floated by gas bubbles. He recommended adding a little calcite to the ores when needed. Minerals Separation,

Ltd., bought this patent in 1903.

Minerals Separation, Ltd.—Organized in 1903 by Ballot, Curle, Webster, Gregory, Sulman and Pickard to acquire the Cattermole patents. Soon after bought the Froment patents. Present processes are based on surface-tension phenomena, accelerated by means of addition to the pulp of small quantities of oil and air in minute subdivision. There is only about 0.1 per cent. oil added, and very violent agitation is indulged in for from 1 to 10 minutes. Innumerable small bubbles of air are thus mechanically introduced which join the oilcoated particles. These are then removed on a spitzkasten. Exposure to air after this treatment then aërates any mineral which has not already taken up its oil film after which a second spitzkasten treatment removes this.

Cattermole.—Added 4 to 6 per cent. of oil, according to the sulphide contents, to a freely flowing pulp, and also 2 per cent. of soap. This process was bought up by Minerals Separation,

Ltd.

Goyder and Laughton.—Their process (1905) was only a variation of the POTTER-DELPRAT. It was used at Broken Hill.

Wolf.—JACOB D. Wolf in 1903 invented a method of applying the principles of flotation. He used sulpho-chlorinated of other oils and aimed to secure a high extraction with a low grade of concentrate in the first step, and by washing with hot water to concentrate the concentrate in a second step. Apparently no commercial use was made of it.

Elmore (Vacuum Process).—In 1904 Francis E. Elmore took out patents covering a process in which flotation is secured by the addition of a small quantity of oil, and by the liberation of air in the pulp in a finely divided condition, this being accomplished by subjecting the freely flowing pulp to a vacuum and simultaneous heating.

De Bavay.—Auguste J. F. De Bavay in 1904 invented a flotation process in which a freely flowing pulp was brought to the surface of a vessel of water, where advantage was taken of the surface tension of the liquid, and the sulphide floated. A film of carbonate on the sulphide, from weathering, is detrimental, and is removed by soaking the ore in a weak solution of carbonate of ammonia, or by passing carbon dioxide through the pulverized wet ore, or by friction. In the original process no oil or acid was used. Later these were also made use of.

Macquisten.—ARTHUR P. S. MACQUISTEN, in 1904, invented a process and a tube apparatus for floating sulphides by surface tension. Oil has since been added to the process. It is operat-

ing at the Morning mill at Mullan, Idaho.

Zinc Corporation.—Organized in 1905 to treat zinc tailing in the Broken Hill district. Tried Potter process in 1905. Remodeled plant in 1907 for Minerals Separation process. In late 1907 and 1908 built an Elmore vacuum mill. In 1910 again

adopted Minerals Separation.

Hyde.—In 1911 James M. Hyde patented a process in which a small amount of sulphuric acid, with or without the use of copperas, is used to give the slimy portion of the ore a preliminary coagulation before flotation. The sulphides, after agitation, are floated off rapidly and as completely as possible with a considerable overflow of freely flowing water, thereby producing an impure concentrate which is re-treated in a second machine. At present the process is being used by the Butte & Superior Copper Co., and is in litigation with Minerals Separation, Ltd.

Murex.—While this process is not strictly of the same class as the others, it still makes use of the principle of selective oiling of sulphide particles. In this process the crushed ore is fed into an agitator and mixed with 4 to 5 per cent. of its weight of a paste made of 1 part of oil or thin tar with 3 or 4 parts of magnetic oxide of iron. This oxide must be ground to an impalpable powder. These ingredients, with enough water to make a pulp, are agitated from 5 to 20 minutes. The paste preferentially adheres to the sulphides because of the oil. The ore is then fed over magnets and the oxide of iron, with the mineral adhering to it, pulled out. The oil and magnetite are then recovered.

Sanders.—This process uses, instead of an acid bath in deep pans, a dilute solution of aluminum sulphate in shallow pans. It was tried by the Tri-Bullion Smelting & Development Co. on a commercial scale, without success.

Horwood.—If a mixture of iron, copper, lead and zinc sulphides is roasted, the three former can be changed to oxide and

sulphide at a comparatively low temperature, whereas the blende is practically unaltered. The partly roasted material is then subjected to a heated-acid oil-flotation process, by which the zinc is floated, the other metals staying behind.

AIR :	IN	ORE	AVAILABLE	FOR	ELMORE	Process ¹
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Proportion of water to ore	Cu. ft. of available air in this water	Lb. of sulphide this will float	Percentage of mineral in the ore		
1:1 2:1 3:1 4:1 5:1 6:1 7:1 8:1 9:1	0.75 1.50 2.25 3.00 3.75 4.50 5.25 6.00 6.75 7.50	60 120 180 240 300 360 420 480 540 600	2.7 5.4 8.1 10.8 13.5 16.2 18.9 21.6 24.3 27.0		

As the proportion of water to ore rarely exceeds 6:1, and as the ores usually yield over 16 per cent. of concentrate, it may be seen that some other gas than that naturally found in the water must be found to effect flotation. This is generally secured by adding limestone to the ore, and then acid at the point where the pulp enters the vacuum chamber.

In general, ore must be crushed to at least 40 mesh to obtain

the best results in flotation.

Ideal ores for flotation processes are said by Hoover to be as follows:

	Pb	Zn	Fe	Cu	Mn	ន	CO ₂	SiO ₂	CaO	Al ₂ O ₃
Acid flotation.	7	20	8 12	3	3	14	3	42 72	1	2

The first is from Broken Hill, the second from Bolivia.

Testing Oils for Flotation²

It has long been recognized that a well-equipped experimental testing laboratory is necessary for the successful working of a flotation concentrating plant. Of the many various tests which are required from time to time, the most frequent and perhaps the most important is the testing of oil, or active floating medium. The following remarks refer chiefly to eucalyptus and resinous oils:

The first material necessary is a standard ore sample. For the

zine," London.

2 Excerpts from an article by J. Courts, in Aust. Min. Stand., Apr. 8,

1915.

¹ T. J. HOOVER'S "Concentrating Ores by Flotation," "The Mining Maga-

purpose of oil testing, a thoroughly representative sample of the material to be treated is dried, crushed to pass 60 mesh and bagged. For convenience, a supply ready for use may be weighed off in 1-lb. lots and put up in small tins.

A sulphuric-acid solution, containing 405 grams of H₂SO₄ per liter, is generally used, 1 cc. of such a solution containing 2 lb. of pure acid per ton, when working on 1 lb. of ore sample.

A standard oil sample is that oil which has been found to fully meet the requirements of the proposition, upon which all future calculations are based and comparisons made. It may be stored ready for use in bottles.

Preliminary Examination

For specific gravity tests hydrometers reading to 0.001 are required. In all cases it is necessary to ascertain the specific gravity of the oil, with the view, at least, to future calculations. This may be carried out at any suitable temperature which has been fixed upon as standard. It has been found advisable to check the specific gravity of the standard oil simultaneously, because of the gradual increase in specific gravity which takes place owing to the loss of lighter oils by volatilization. A correction for temperature is made by allowing 0.00045 for each deg. Fahrenheit.

A small burette is used for counting the number of drops in 1 cc. of the oil, also for admitting the oil to the machine during testing operations. The greater the number of drops delivered by the burette, the greater the accuracy of the test. To obtain a suitable dropper, cut a burette about 8 in. above the cock, almost close the discharge orifice by dumping up the glass with a blowpipe flame, then grind the outside back to a point so that a minimum surface is presented to the oil drop. The burette should at normal temperatures give between 80 and 90 drops per cubic centimeter, when run at the rate of 1 drop per second. The temperature of the oil during dropping test should correspond with the temperature during flotation test.

Having obtained the number of drops per cubic centimeter and the specific gravity, it is easy to calculate the number of pounds of oil per ton of ore, when working on 1 lb. of sample.

Thus $\frac{2240 \times sp. \ gr.}{453.6 \times drops \ per \ cc.} = lb. \ of \ oil \ per \ long \ ton.$

It is sometimes desired in practice to use a mixture of oils. When the oil under examination is to be used in conjunction with other oils, these should be wholly miscible in the propor-

tions in which they are to be used.

The following classification and explanations will serve to give a general idea of the methods employed when carrying out various tests: (1) flotation of lead, zinc and other sulphides, as a mixed concentrate; (2) differential separation, or selective flotation of one sulphide in the presence of other sulphides (the term "differential separation" is usually applied to the selective flotation of lead sulphide from zinc and other sulphides); (3) flotation of copper and iron sulphides.

Outline of Test Process

The testing of oils in the laboratory is carried out by comparing measured quantities (from 3 to 6 drops) of a standard oil, with a similar quantity of the oil under examination, the values being arrived at by comparing the results obtained from each series of tests. Tests are usually made on 1 lb. of standard ore sample in 4 lb. of water at a standard temperature, acidulated with a definite quantity of sulphuric acid. The oil then being admitted, the mixture is agitated in a specially constructed agitating machine, the principle of which is dependent on the object of the test. The float produced is skimmed off, dried,

weighed and assayed.

The Flotation of Mixed Sulphides.—Almost any eucalyptol oil which produces a persistent froth, and leaves a gummy residue on evaporation, is suitable for this class of work. An agitating machine may be constructed by cutting a packing bottle about 10 in. above the neck (a bell jar of suitable dimensions can be obtained). Fit four copper baffles, $4 \times 1\frac{1}{2}$ in. wide, to a copper band of the same width and push this arrangement hard down into the bottle (the band being first bent to fit the inside circumference of the bottle). The lower ends of the baffles will jam hard to a point where the concave glass begins. The band is then expanded hard against the glass, and held in position by soldering the separated ends. The mouth, or discharge end, is closed with a rubber stopper, through which is passed a glass or metal tube fitted with a short rubber tube and clip. The bottle with the baffles in position is inverted and clamped centrally under two pairs of suitable bearings, which carry a 1/2-in. impeller shaft. At the upper end of the shaft is fitted a driving wheel, and at the lower end a fourbladed impeller which just has clearance between the lower points of the baffles and the glass. The blades of the impeller have a lateral angle of about 45° and should be driven at about 1200 r.p.m. in a lifting direction.

Test 2. Differential Separation.—For differential separa-

Test 2. Differential Separation.—For differential separation, an oil high in phellandrene which leaves a gummy residue on evaporation is used. Phellandrene may be tested for by a polariscope. Differential separation is worked in acid and neutral and in hot and cold liquors, and being still in its infancy, allows of many types of machines and schemes. Each different ore requires some modifications, but the principal in main is the addition of medium and aëration from below, which is effected

by air jets or suction created by the impeller.

Test 3. Flotation of Copper and Iron Sulphides.—An oil which gives a deflection by the polariscope of 60 or over is considered sufficiently high in phellandrene for use in copper flotation. Tests are usually made with the apparatus described in Test 1, using cold circuit liquors made slightly acid. In practice the mine water usually contains sufficient acid for the purpose.

RECENT PROGRESS IN FLOTATION1

Certain progress in the more general details of flotation milling is of interest. For instance, it now looks as if much of the older concentrating machinery is going to be displaced by flotation machinery. The first application of flotation was to retreat slimes carrying valuable sulphides, and it was hence merely an addition to slime-treating machinery, such as vanners and slime tables. Soon the vanner heads instead of the tails were being tested in the flotation machines, and the results have varied greatly. In some places the flotation machines are still treating the vanner or slime-table tails; in others the tests have shown better work with the older slime-treating machinery entirely eliminated. Of course, the criterion used has been the

economy of concentrating the various ores in question.

Although slime-treating machinery could now be almost entirely dispensed with, there is still some doubt in many cases as to the advisability of doing so. However, some men have gone much farther and have suggested that it may be advisable to displace the sand-concentrating tables and to grind all material for direct treatment by flotation. In fact, one large copper company has decided to displace all concentrating machinery with the exception of rougher tables and regrind the tails from these for flotation. But with, say, a lead- or a zinc-sulphide ore containing the valuable minerals in large clean crystals it is hard to see why such a practice should be necessary. It would seem that only the fines and slimes, which are inevitably produced by any crushing, should require flotation treatment. This, of course, leaves out of consideration the cases where heavy gangue minerals make mechanical concentration of other kinds difficult.

"Cleaning" Flotation Products

The practice of "cleaning" both flotation concentrates and tails is another development, at least in American practice.

Only a few years ago "rougher" and "cleaner" units were not commonly spoken of. Now almost every installation, of whatever type, is retreating the concentrates from a "rougher" machine in a "cleaner" machine in order to drop out most of the gangue material and some of the middlings which need further treatment. Moreover, it is becoming customary to add suitable oils to the tailings for further flotation treatment in order to produce clean tailings and a low-grade middling product. These various middling products are reground in the best practice and returned to the circuit, while in other instances simple return of middlings without regrinding is common. Another point of interest has been the installation of all manner of "drag" devices for removing any froth that may form on the pulp in the subsequent handling of tailings, such as in dewatering or thickening. It is also a debated question as to whether

¹ Excerpts from an article by O. C. Ralston and F. Cameron, Eng. and Min. Journ., May 29, 1915.

further flotation treatment before discharge is not better

practice.

Another development when using pneumatic cells of the Callow type has been to add "recleaners" for further treatment of the concentrates from the froth "cleaners." Thus we have "roughing" machines followed by "cleaners" for the tailings, and, in some installations of the Callow type "cleaners" and "recleaners" for the concentrates. As a matter of fact, the same general sequence of treatment is followed in the many compartments or cells, in series, of the Minerals Separation type of machine.

Breaking Up the Froth

The further handling of froth concentrates has proved a serious problem for many operators when the froth has been tough and permanent. The most common method of breaking froth is by jets or sprays of water. A single strong jet of water turned on the flowing froth in a launder often results in material benefit, and a water pipe perforated with many holes to give . more jets is better, while special sprays, such as rotating garden sprays (inverted), Buffalo sprays, etc., prove even more efficient. Direct feed into a filter of the pressure-filter type is most efficient, as the froth does not need to be broken up. The vacuum filters are not so well adapted to immediate treatment of the froth because it generally is too thin (25 per cent. to 35 per cent. solids) to cake well; vacuum filters of the Portland or OLIVER type require approximately 50 per cent. solids in the pulp. However, by breaking the froth and dewatering, a vacuum filter is permissible. In a number of installations a bucket elevator seems to break up the froth to a satisfactory extent, actual tests made by one company indicating 80 per cent. efficiency in breaking froth, merely in the passage of the froth through the bucket elevator. Addition of chemicals, such as acid or lime, or of more oil to the froth, also tends to break it down and make the solids settle out well. If lime be used for this purpose, the mill water cannot be used again without neutralizing.

Settling of froth in bins for dewatering, while a common practice, is not satisfactory, as it practically imposes a canvas lining for the car in which the concentrates are shipped, and concentrates shipped in this manner will drain in such a "traveling filter" to about 25 per cent. or 30 per cent. moisture. In case of a long haul, this is expensive both in freight and leaks. Filters are being used in nearly all of the larger plants. Oliver and Portland filters turn out a satisfactory product with 10 per cent. to 15 per cent. moisture, and pressure filters like the Kelly while more cumbersome and expensive to operate, are giving products ranging from 6 per cent. to 10 per cent. moisture.

Flotation Practice with Complex Sulphides

Where the flotation concentrates consist of several mixed sulphides which it is advisable to separate they are run over concentrating tables after breaking the froth. This idea is old,

but its application in the United States is relatively new. Mixed concentrates made on Minerals Separation, Callow, McQuisten and De Bavay machines are now being treated in this manner in the United States.

The mention of separation of mixed sulphides in flotation concentrates suggests the work on preferential (selective) flotation. In this field there is much work being done in laboratories, and many seemingly good results are being obtained. However, most work of this kind is being guarded closely. In four separate and distinct places the idea has been adopted of separating galena selectively in the presence of sphalerite by an exact proportioning of a suitable oil, adding only enough to float the galena. This idea is old, but to see it worked out in detail and applied in the works (as it is in three instances) is

gratifying.

Most of the preferential methods have consisted in the treatment of ore by some method which modifies one of the flotative minerals and prevents its floating. The Horwood process (a slight roast to deaden the surfaces of lead-sulphide particles and prevent their floating, while the zinc sulphide is unaffected) has been tried experimentally in at least five instances, and more or less encouraging results have been obtained. A patent of Greenway and Lowry reveals another proposal of adding chromates to the mill water to act on one sulphide while the other is unaffected and can still be floated. Still other methods of getting preferential flotation have been experimented with—by proper preliminary treatment of the oil, such as emulsifying, fractionally distilling, treatment with proper electrolytes, acids or other chemicals. This work is nearly all experimental-laboratory work.

Retreatment of Tailings

The cleaning of tailings is being accomplished, as a rule, by further addition of oil and retreatment in other flotation cells. The "step" addition of oils is claimed by the Butte metallurgists as a contribution of their own. Almost universally, oleic acid is used in the cleaning treatment of the tails of lead- or zinc-sulphide ores. It seems to be especially adapted to the purpose, though it is hard to get high-grade concentrates by its use.

Incidentally, the effect of adding an excess of any flotation oil seems to be the formation of lower grade concentrates, which are hard to clean. Moreover, the froth is liable to be too tough and permanent to permit of its being easily broken after removal from the machine. Oil or substances immiscible with water and generally understood by that name are not necessary to flotation. Many soluble frothing agents are used that are not "oils" in any sense of the term. As the term "soluble frothing agents" has been mentioned in many of the more recent patents, the term "oil flotation" might be advantageously dropped. before it gains too much headway.

Flotation Oils

The subject of oils is a most important one, and more experimental work has been done on this particular phase of the subject than on any other. Attempts to determine which oils may be best suited to the treatment of certain minerals have not resulted in deciding on any particular oil that will always concentrate a certain mineral in all cases. Pine oil is a favorite for floating both lead and zinc sulphides, though the wood creosotes are close competitors. Eucalyptus oil seems in many cases to work better than either of these, but it is too costly.

Petroleum products appear to be sufficiently selective for copper concentration; but in the concentration of lead or zinc sulphides they seem to float too much gangue. Such being the case, it may be said that petroleum oils are not well adapted to flotation work upon lead-zinc ores, as in the treatment of such ores it is necessary to produce concentrates which shall contain not less than 45 per cent. lead or zinc. On the other hand, particularly high-grade concentrates are not necessary in copper work, and a high extraction, with concentrates having a tenor of 10 per cent. to 25 per cent. Cu, is usually obtainable.

Delivered, pine oil costs from 25 cts. to 30 cts. per gallon; creosote 18 cts. to 25 cts.; eucalyptus oil, \$1.50 to \$2 per gallon. (Roughly, there are 8 lb. of oil in a gallon.) The petroleum products used can be bought for from 5 cts. to 10 cts. per gallon.

Use of Acid in Flotation

In the use of acid in the mill water the practice differs sharply. The addition of acid seems to improve selective action, especially on galena, sphalerite and pyrite, and appears to be effective for the purpose of getting clean concentrates with a minimum of gangue. The removal of oxidized films from sulphide particles is one result. It could doubtless be used in many places where it is not now used. On the other hand, it has been found in certain instances that the presence of an acid was fatal to the process. As a rule sulphuric acid is the cheapest acid available and so is generally the one used. The amount of acid used is somewhat lower than formerly, when from 0.5 per cent. to 1 per cent. H₂SO₄ was used in the mill water. Now the average

practice is from 0.2 per cent. to 0.5 per cent.

The presence of any electrolyte seems to have a marked effect on flotation, and a set of experiments on some wellknown ore, using distilled water instead of mill water, is therefore of great interest. In fact, the analysis of mill water from some of the mills where different methods are employed for treating ores that seem to be almost identical may reveal some interesting points. In our own laboratory the possibilities of new conditions arising from the use of water from the Great Salt Lake

is a question under investigation.

Temperature Increases Selective Action

Whether temperature is an important item or not is also under dispute. On nearly every ore being treated it is possible to get good work done with unheated mill pulp; but a better grade of concentrates can often be obtained by heating the solution. It makes the oil and water less viscous, so that a given amount of oil will go a little farther. Moreover, less gangue rises through the more fluid water. The consideration of what would happen in the way of flotation of gangue if a mill solution composed of thick molasses were used illuminates this point. Further, the selective action due to the presence of an acid or electrolyte is promoted by a higher temperature. Hence, heating the mill pulp will be of value in those instances where concentrates of high metal tenor are wanted, as when working on lead- and zinc-sulphide ores. The temperature to which the mill water is heated is not over 65°C. (149°F.) in any case, and usually not over 50°C. (112°F.). The cost of heating to these temperatures is from 5 cts. to 10 cts. per ton of dry slimes.

Developments in Mechanical Agitation

The tendency in all mechanical-agitation methods of flotation (as distinguished from pneumatic methods) seems to be toward the most careful and rigid practice possible. A study is being made of the exact proportioning of compartments, of the beating blades or paddles on the impellers, and of the spitz-kasten or settling boxes. For example, inclined blades seem to wear better than vertical ones.

The addition of froth rakes or hoes has also been made to nearly all such machines so as to remove the froth as fast as it is formed rather than to let it accumulate until it overflows by gravity. The removal of the froth in this manner avoids the breaking of bubbles and thus prevents the mineral getting back into the pulp and being lost. It also increases the capacity of the machine and permits the use of only enough oil to give a

froth that breaks easily and carries little gangue.

Individual drive of each impeller from a small special motor has been adopted in one design, rather than the use of a line shaft with either belt or gear drive of each impeller. This drive doubtless costs much more for installation, but gives flexibility of control of each individual cell. Other mechanical means of mixing are being tried, such as the centrifugal pump which was used in Australia some time ago. This arrangement seems to give a low extraction and high-grade concentrates, a result capable of explanation on the assumption that the flotation conditions obtained are rather poor and that hence only the purest mineral floats, while middlings are unaffected. Such a practice makes cleaning of the tails by further treatment necessary. Having adjustable openings between beating compartments and spitzkasten seems to be nearly universal practice, though in a few of the mills visited the openings are hardly ever manipulated.

A preliminary mixing of the oil with the pulp is suggested as an interesting possibility as a result of some experiments conducted by three large companies, in which the addition of the oil was made before the material treated was passed through a tube mill. The mixing conditions were ideal and the tube-mill discharge could be run directly into a spitzkasten for separation of froth, or into pneumatic-flotation cells. This idea will doubtless be followed further.

Variation in Pneumatic-flotation Cells

Contrary to the tendency in mechanical-agitation schemes, the pneumatic-flotation machinery is being modified, apparently, toward the greatest freedom of design possible. As an instance, the Callow cell is designed with a slanting bottom to facilitate discharge of tailings. Some mill men find flat bottoms to work just as well. In fact, every possible modification of a bottom seems to be at work. Single and quadruple thicknesses of canvas are used. The canvas may be clamped and bolted between two strong grids of perforated sheet steel or it may be supported against some wire cloth and tacked on. It may likewise not be supported in any manner, but simply stretched tight and held by a piece of rope driven in a groove which extends around the inside of the bottom of the machine. The last-cited method seems to be about as successful as any for changing bottoms when the canvas becomes worn out.

Before treatment in the pneumatic-flotation cell the pulp is commonly mixed with the oil in a Pachuca mixing tank. In several instances a number of these Pachucas are placed in series and a good grade of froth is drawn direct from the tops of them. It is quite likely that radical changes in design-will result from this experimental work. Both wooden and metal constructions are used, the metal cells costing nearly twice as much as the

wooden ones.

Electrical Flotation

Among the new proposals appearing during the last year was the Fields electric-flotation process. In this process it is proposed to accomplish flotation by means of hydrogen bubbles developed by electrolysis of the solution mixed with the pulp. Fields also proposes to use air lifts to keep the pulp in suspension. It is claimed that no oil is necessary, but that it helps. The special application of this process is stated to be on partly oxidized copper ores, where the copper sulphides can be floated, and by use of a solution of a sulphate or a chloride the oxidized copper will go in solution at the anode and a rough copper cathode will finally result. Promising results have been obtained, but at an expenditure of power of about 10 times that anticipated. Whether or not this process can be made commercially feasible is a matter of considerable interest.

Flotation of Oxidized and Other Minerals

In the flotation of oxidized and other minerals much quiet work is being done. The most promising method proposed is that of "sulphidizing" oxidized minerals of copper and of lead by treatment with the proper soluble sulphide and then floating the artificial sulphides formed. This idea has been tried principally on copper ores with fair results. Treatment with hydrogen-sulphide gas, either of dry ore or suspended pulp, works well, or the sulphidizing may go on during flotation by use of ground matte and acid to react on each other and form H₂S; or solutions of hydrogen sulphide, alkaline sulphides, alkaline-earth sulphides and other compounds can be used with more or less success. The concentrates formed are never of high grade, as a great deal of gangue is carried up, especially iron. Similar work is being done in our laboratory on low-grade oxidized ores of lead, but a concentrate with only 20 per cent. of lead is a different thing from a 20 per cent. copper concentrate. The present outlook seems to be that the process will apply only to oxidized copper ores. Oxidized zinc ores seem to be unaffected by the process.

Characteristics of Oils

In general, oils may be broadly divided into "frothers" and "collectors." The pine oils are good frothers and coal tar and its various subdivisions are good collectors. On some ores, according to the General Engineering Co., crude pine tar will in itself combine both the properties of frothing and collecting. On others this may have to be enriched by the addition of some one of its more volatile constituents, such as refined pine oil,

turpentine or wood creosote.

Generally speaking, the coal-tar products are poor frothers, and to get a sufficient volume of froth to insure a high recovery it is often necessary to add refined pine oil, creosote, etc. At Inspiration, for instance, the mixture is 80 per cent. crude coal tar, 15 per cent. light oil or creosote, 5 per cent. pine oil; at Daly-Judge, 40 per cent. crude coal tar, 40 per cent. creosote, 20 per cent. pine oil; in the Coeur d'Alenes, on zinc ore straight wood creosote; on the National copper ore plain turpentine will work, but pine oil is better. At Inspiration, from 1½ to 2 lb. of the mixture per ton of ore, at Daly-Judge 1 to 1½ lb. and at the National ¾0 lb. of oil is sufficient. The proper kind or kinds of oil and the quantity requisite can only be determined at present by tentative experiment.

Calculation of Mill Recovery

If h = heads assay; t = tailings assay; c = concentrates assay; r = ratio of concentration; e = per cent. recovery.

$$r=\frac{c-t}{h-t};\ e=\frac{100c}{rh}$$

SECTION VII

CYANIDATION

Flow of Sand and Water through Spigots1

RELATION OF COMPOSITION TO VISCOSITY OF MIXTURES OF SAND AND WATER

Kilo- grams sand and water	Kilo- grams sand	Kilo- grams and liters water	Liters sand	Liters sand and water	Per cent. sand by volume	Per cent. sand by weight	Vis- cosity of mix- ture
9.20	0.00	9.20	0.000	9.20	0.00	0.00	1.00
9.30	0.45	8.85	0.165	9.02	1.83	4.84	1.02
9.35	1.10	8.25	0.405	8.66	4.68	11.8	1.06
9.35	1.40	7.95	0.515	8.47	6.08	15.0	1.09
9.40	1.90	7.50	0.699	8.20	8.53	20.2	1.12
9.40	1.95	7.45	0.717	8.17	8.78	20.8	1.13
9.55	2.20	7.35	0.809	8.16	9.92	22.0	1.13
9.20	2.25	6.95	0.827	7.78	10.6	24.4	1.18
9.05	2.50	6.55	0.920	7.47	12.3	27.6	1.23

A concrete example, illustrating the use of the data given above, may prove of interest. It is desired to discharge from the pocket of a classifier 40 tons of sand per 24 hours together with water in the ratio of 1 part of sand to 3 parts of water by weight. The head of water above the spigot is 3 ft. The form of the spigot is that of a short tube with a conical mouth on the influx end. The mean specific gravity of the sand is 2.81. What must be the diameter of the spigot opening? For the sake of convenience, metric units are used in making the calculation. The area of the spigot opening may be obtained from the formula:

$$a = \frac{fq}{c \sqrt{2gh}}$$

Taking up the terms on the right hand of the equation in order, f the viscosity, may be estimated as follows: The weight ratio of water to sand in the mixture to be discharged is 3 to 1. Considering 100 grams of the mixture, the weight of water is 75 grams; its volume is 75 cc. The volume of the sand is 25 grams \div 2.81 (the density of the sand) = 8.9 cc. The total volume of 100 grams of the mixture is 75 + 8.9 = 83.9 cor Hence the percentage of sand by volume in the mixture is $8.9 \div 83.9 = 10.6$. From the lower curve of Fig. 1, the viscosity of a mixture containing 10.6 per cent. of sand by volume is 1.17. Therefore, f = 1.17. The quantity of sand discharged per 24 hours is 40

¹ RICHARDS and DUDLEY, Trans. A. I. M. E., January, 1915.

One ton per 24 hours is 0.631 kg. per minute. tons per 24 hours is $40 \times 0.631 = 25.2$ kg. per minute. volume of sand per minute is $25.2 \div 2.81$ (the density) = 8.98 liters. The quantity of water per minute is three times that of the sand, $25.2 \times 3 = 75.6$ kg. = 75.6 liters. The total volume of sand and water per minute is 8.98 (sand) + 76.5 (water) $= 85.5 \div 60 = 1.43$ liters = 1430 cc.

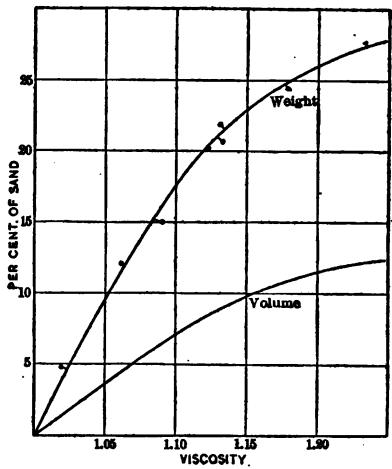


Fig. 1.—Graphic representation of results shown in table on p. 403.

Since the spigot is to consist of a short tube with a conical mouth on the influx end, the coefficient of discharge, c, may be assumed as 0.88. Substituting these values in the above equation gives for the area of the spigot opening:

$$a = \frac{1.17 \times 1430}{0.88 \sqrt{2 \times 980 \times 914}} = 1.42 \text{ sq. cm.}$$

The diameter may be obtained from the relation:

$$d = 2 \sqrt{\frac{a}{n}} d = 1.35 \text{ cm.} = 0.53 \text{ in.}$$

Pulp Constants

In an article by G. H. CLEVENGER, H. W. Young and T. N. TURNER (Eng. and Min. Journ., Dec. 19, 1914) it was shown that the ordinary calculations for contents of tanks, weights of tailings, etc., based on the assumption that the specific gravity of the solution was 1, were incorrect by large amounts. VENGER worked out a set of complete tables covering these constants, of which only the basic formulas are here given.

Tet a =Specific gravity of wet pulp. S =Specific gravity of dry slime.

V = Total volume of wet pulp.

m = Total weight of dry slime in wet pulp.

c =Volume of solution in wet pulp.

d = Specific gravity of solution.

P = Percentage of dry slime in wet pulp.

$$a = \frac{m + cd}{V} \qquad S = \frac{m}{(V - c)}$$

Solving for c, equating values, simplifying and solving for m:

$$m = \frac{SV(a-d)}{(S-d)}$$

P is obtained by multiplying the above value of m by 100 and dividing by weight of the wet pulp, Va:

$$P = \frac{100S(a-d)}{a(S-d)}$$

The error introduced by assuming d = 1 is not a negligible one.

SPECIFIC GRAVITY OF WORKING CYANIDE SOLUTIONS

Solution	Specific gravity				
Fresh solution Butters plant, Virginia City, Nev Butters plant, Virginia City, Nev Belmont plant, Tonopah, Nev Belmont plant, Tonopah, Nev Montana-Tonopah, Tonopah, Nev Empire, Grass Valley, Calif Portland, Colorado Springs, Colo South Africa, average Pittsburgh-Silver Peak, Blair, Nev	Tails Heads Tails Heads Heads Heads	1.00170 1.00281 1.00279 1.00881 1.00873 1.00314 1.00142 1.01000 1.00210 1.00309			

SLIME COAGULANTS¹

Substances	Quantities required by weight, to pro-
49	duce equal effects
Aluminum sulphate	100
Alum (potash)	143
Ferric sulphate	223
Alum (ammonium)	252
Alum (ammonium-chromium)	295
Lime	654
Magnesia	
Alum (potassium-chromium)	958
Calcium chloride	1,095
Calcium carbonate	\dots 1,215
Calcium sulphate	2,870
Magnesium sulphate	3,460
Sodium chloride	45,900
Sodium sulphate	61,700

¹ Megraw, "Practical Data for the Cyanide Plant," adapted from Julian and Smart.

Number of Cubic Feet for each Foot of Depth of Cylindrical Tanks¹

n., nes					Dia	meter,	feet				
Diam.,	10	11	12	13	14	15	16	17	18	19	20
0 1/2 1 1/2 2 1/2 3 1/2 4 1/2 5 1/2 6 1/2 7 1/2 8 1/2 9 1/2 10 10 1/2 11 11 1/2	79.19 79.85 80.51 81.18 81.85 82.52 83.19 83.86 84.54 85.22 85.90 86.59 87.28 87.97 88.66 89.36 90.06 90.76 91.47 92.18 92.89 93.60	95.75 96.48 97.20 97.93 98.66 99.40 100.9 101.6 102.4 103.1 104.6 105.4 106.9 107.6 108.4 109.2 110.0 110.7	113.9 114.7 115.5 116.3 117.1 117.9 118.7 119.5 120.3 121.1 121.9 122.7 123.5 124.4 125.2 126.0 126.8 127.7 128.5 129.4 130.2	133.5 134.4 135.3 136.2 137.0 137.9 138.7 139.6 140.5 141.4 142.2 143.1 144.0 144.0 145.8 146.7 147.6 148.5 149.4 150.3 151.2 152.1	154.8 155.8 156.7 157.6 158.5 160.4 161.4 162.3 163.2 164.1 165.1 166.0 167.9 168.9 169.9 170.9 171.8 172.8 173.8 174.8	176.7 177.7 178.7 180.7 181.7 182.7 183.7 184.7 185.7 186.7 187.7 190.7 191.7 192.8 193.8 194.8 195.8 195.8 195.0 200.0	202.1 203.2 204.2 205.3 206.3 207.4 208.4 209.5 211.7 212.7 213.8 214.9 216.0 217.1 218.2 219.3 220.4 221.5 222.6 223.7 224.8	228.1 229.2 230.3 231.5 232.6 233.7 234.8 236.0 237.1 238.2 239.3 240.5 241.6 242.8 243.9 245.1 246.2 247.4 248.6 249.8 250.9	255.6 256.8 258.0 259.2 260.4 261.6 262.8 264.0 265.2 266.4 267.6 268.8 270.0 271.2 273.7 274.9 276.1 277.3 278.6 279.8 281.0	284.7 286.0 287.2 288.5 289.7 291.0 292.3 293.6 294.8 296.1 297.3 298.6 299.9 301.2 303.8 305.1 306.4 307.6 308.9 310.2 311.5	315.5 316.8 318.1 319.4 320.7 322.1 323.4 324.7 326.0 327.4 328.7 330.1 331.4 335.5 336.8 336.8 339.5 340.9 342.2 343.6

Number of Cubic Feet for each Foot of Depth of Cylindrical Tanks. 1 Continued

n., bes					Dia	meter	feet				
Diam., inobes	21	22	23	24	25	26	27	28	29	30	31
0 14 11/2 21/2 31/2 4 41/2 51/2 61/2 7 71/2 81/2 91/2 10 10/2 11 11/2	347.7 349.1 350.5 351.9 353.3 354.7 356.0 357.4 358.8 360.2 361.6 363.1 364.5 365.9 367.3 368.7 370.1 371.5 372.9 374.4 375.8	381.5 383.0 384.4 385.9 387.3 388.8 390.2 391.7 396.1 397.6 399.1 400.6 402.0 403.5 405.0 406.5 411.0 412.5	417.0 418.5 420.0 421.5 423.0 424.6 426.1 427.6 429.1 430.7 432.2 433.7 435.2 436.8 438.3 439.9 441.4 443.0 444.5 446.1 447.7 449.3	453.9 455.5 457.1 458.7 460.3 461.9 463.4 465.0 466.6 468.2 469.8 471.4 473.0 474.6 476.2 477.9 479.5 481.1 482.7 484.4 486.0 487.6	492.5 494.2 495.8 497.4 499.0 500.7 502.4 504.1 505.7 507.4 509.0 510.7 512.3 514.0 515.7 517.4 520.8 522.4 524.1 525.8 527.5	532.6 534.3 536.0 537.8 539.5 541.2 542.9 544.6 546.3 548.1 549.8 551.5 553.2 555.0 556.2 562.0 563.7 565.6 567.2 569.0	574.3 576.1 577.8 579.6 581.4 583.2 585.0 586.8 590.4 592.2 594.0 595.8 601.2 603.0 604.8 606.6 608.4 610.2 612.1	617.6 619.4 621.2 623.1 624.9 626.8 628.6 630.5 632.3 634.2 636.0 637.9 645.4 647.3 645.4 647.3 649.2 651.0 652.9 654.8	662.4 664.3 666.2 668.1 670.0 672.0 673.9 675.8 677.7 679.6 681.5 683.5 685.4 689.3 691.2 693.1 695.1 699.0 700.9	708.8 710.8 712.7 714.7 716.7 718.7 720.7 722.7 724.6 728.6 736.6 736.6 736.6 740.6 742.0 744.6 748.7 750.7	754.8 756.8 758.8 760.8 762.9 764.9 767.0 769.0 771.1 773.1 775.2 777.2 779.3 781.3 785.5 787.6 789.6 791.7 793.8 795.9 798.0 800.1 802.1

Number of Cubic Feet for each Foot of Depth of Cylindrical Tanks. 1 Continued

Diameter,				Di	Diameter, feet										
inches	32	33	34	35	36	37	38	39	40	41	2				
0	804.2	855.3	907.9	962.1	1018	1075	1134	1195	1257	1320	1385				
14				964.4											
1				966.7											
134	810.5	861.8	914.6	969.0	1025	1082	1141	1202	1264	1328	1393				
2	812.6	864.0	916.8	971.3	1027	1085	1144	1205	1267	1331	1396				
234	814.7	866.1	919.0	973.6	1029	1087	1146	1207	1269	1333	1399				
3	816.9	868.3	921.3	975.9	1032	1090	1149	1210	1272	1336	1402				
312	819.0	870.5	923.5	978.2	1034	1092	1151	1212	1275	1339	1405				
4	821.1	872.7	925.8	980.5	1037	1095	1154	1215	1278	1342	1408				
432 -	823.2	874.8	928.0	982.8	1039	1097	1156	1217	1280	1344	1410				
5	825.3	877.0	930.3	985.2	1042	1100	1159	1220	1283	1347	1413				
532				987.5											
6				989.8											
614				992.1											
7				994.5											
71/2				996.8											
8				999.1											
81/2	840.2	892.4	946.1												
9		894.6								1369					
91/2		896.8								1371					
10		899.0								1374					
1012		901.2								1377					
11		903.5								1380					
1132	853.1	905.7	959.8	1015	1072	1131	1192	1254	1317	1382	1450				

Number of Cubic Feet for each foot of Depth of Cylindrical Tanks. Continued

Diameter,					D	i a met	er, fe	et				
inches	43	44	45	46	47	48	49	50	51	52	53	54
0 .	1452	1521	1590	1662	1735	1810	1886	1963	204 3	2124	2206	2290
34	1455	1523	1593	1665	1738	1813	1889	1966	2046	2127	2209	2293
1											2213	
132											2216	
2											2220	
21/2											2223	
3											2227	
314											2230	
4											2234	
434											2237	
5											2241	
51/2											2244	
6											2248	
634											2251	
7											2255	
732											2258	
8											2262	
812											2265	
9											2269	
914											2273	
10											2276	
101/2											2279	
11											2283	
1132	1518	1587	1659	1732	1806	1882	1960	2039	2120	2202	2286	2372

424 METALLURGISTS AND CHEMISTS' HANDBOOK

NUMBER OF CUBIC FEET FOR EACH FOOT OF DEPTH OF CYLINDRICAL TANKS. 1 Continued

Diameter.				Dian	neter,	feet				
inches.	55 56	17	58	59	60	61	62	63	64	9.5
	2200 140		1045		onas	47000	2010	2445		
0,	2376 246					2922		3117	3217	33
3-3	2379 2468				2831	2026	1023	3121	3221	33
1.,	2383 2470	_				2930		3125	3225	33
114	2 (86, 247)	2 11 3	21 10			2934		3129	3229	3.8
2	2390 2475	211	41.14	2749	2843		3035	3134	3234	
216	2393,21%		-1901	2753	2847			3138		10.0
3	2397,24%	12114				2046		3147	3242	
-31"	240 L Z480	2333	519941	2761				3146		33
4.	2405 24-5	2 182	7.4	2760	25.09			31 (0)	3251	33
412	2415 244		24.76	2760						33
5	2412 2 48	Fabrica	Tarte of			2963		3159	3259	3.3
5 va	241501					2967		-2- 8 2-	3243	33
6	2419-2504	. 97	3990				3068		3267	33
61 z	2422.2511	_(-)(-	5003		2879		3072	3171	3271	33
7	2426 2511	fit a	3600	2755	2933		3076	3175	1276	33
712	24.80.2545	CLUDS	26.35	2792	-887	2953	3080	3179	3250	33
8	24.34 2524	2612	27 2	2796	2891	2987	3084	3184	3284	33
24.52	2437 2 2	21.2	_7.77	2800	2895	2991	3058	3188	3288	33
9	2411 1 29	6,611	27 (4)	2804	2899	2995	3093	3105	3293	33
912	2444	2525	.7.	250	2903	2999	3097	3190	3297	33
0.1	2448 9	20.2	.71)	2512	2907	3003	3101	3200	3301	34
10^{12}	24 5	2630		251E		3007	3105	3204	3 305	34
11	2456 2 44	2634	27.20	2820	2914	3011	3100	3209	4310	34
1612	24 19 . 313		4741	2823	291N	3015	3113	3213.	3314	34

NUMBER OF CUBIC FEET FOR EACH FOOT OF DEPTH OF CYLINDRICAL TANKS. 1 Continued

Diameter	Diameter, feet											
inches	66 6	7 68	69	70	71	72	73	74	75	7		
	7 7	7	17	T 1	1050	70	4100	. 201	1	1		
0		20 10-12							4418			
12	3425 55			15.5.1				4306		_		
	3430 35			1555					4424			
112	3434 15							4315		-		
2	345% 5 2		757	3507				4320	4			
212	3142 15			3571	_				4442	-		
3	3447 5 >	- 85		1576				4330		М		
312	3451 10		. , ,						44.25	-		
4	34 11 1 11							4340	7 7 7 7	-		
432	3461 151				_			4 144	4463	-		
5.	· · · · · · · · · · · · · · · · · · ·	34 3572		_	\$4.cle				4467			
5.52	Man s	1 115	1 2 4 1					4354	4472	-		
6	347333		4450									
615	3477 (1)		3798		4020							
7.		87 34 H			1 -				4457			
742		त उट्ट	1817	1117	1, 1,21)	414-			44/45	-		
8	3491 53		5 51 -	3 A.	1 134	4147	1262			Ш		
P(3)2	3495 20	,		3 - 23					4502			
9	3449 566	, , , , ,		51 >					4 807	-		
911	3503 Int		39.7	3-1-1				4 30-3		40		
10		F Cal		444				4 395		46		
10 va	3512 351									40		
11	3, 17, 30,		1 (4,31)	3 P W	40.0%	4170	4201	440K	4527	46		
1.130	3521 30.	27 3734	154.5	1374	4007	4130	4296	4413.	4531	66		

Number of Cubic feet for each Foot of Depth of Cylindrical Tanks. Continued

Diameter,				I	diame	ter, fe	et				
inches	77	78	79 ,	80	81	82	83	84	85	86	87
0 .	4657	4778	4902	5027	5153	5281	5411	5542	5675	5809	594
36	4662	4783	4907	5032	5158	5286	5416	5547	5680	5814	5950
1	4667	4789	4912	5037	5164	5292	5421	5553	5686	5820	5956
1 3 2	4672	4794	4917	5042	5169	5297	5426	5558	5691	5825	5961
2	4677	4799	4922			5303					
21/2	4682	4804	4927			5308					
3	4687	4809	4933			5313					
31/2	4692	4814	4938			5318					
4	4697	4819	4943			5324					
41/2	4702	4824	4948			5329					
5	4707	4830	4954			5335					
51/2	4712	4835	4959	5084	5211	5340	5470	5602	5735	5871	6007
6	4717	4840	4964	9509	5217	5346	5476	5608	5741	5877	6013
614	4722	4845	4969			5351					
7	4727	4850	4974			5356					
71/2	4732	4855	4979			5361					
8 .	4738	4860	4985			5367					
81/2	4743	4865	4990			5372					
9	4748	4871	4995	5121	5249	5378	5509	5641	5775	5911	6048
91/2	4753	4876	5000			5383					
10	4758	4881	5006			5389					
1034	4763	4886	5011			5394					
11	4768	4891	5016			5400					
111/2	4773	4896	5021	5147	5275	5405	5536	5669	5803	5939	6076

Number of Cubic Feet for each Foot of Depth of Cylindrical Tanks. Continued

Diameter,	T				D	iamet	ter, fe	et				
inches	88	89	90	91	92	93	94	95	96	97	98	99
0	6082	6221	6362	6504	6648	6793	6940	7088	7238	7390	7543	769
1/2					6654							
1 .	6094	6233	6374	6516	6660	6805	6952	7101	7251	7403	7556	771
11/2					6666							
2	6105	6244	6385	6528	6672	6817	6864	7113	7263	7415	7569	772
21/2					6678							
3					6684							
31/2					6690							
4					6696							
41/2	6134	6274	6415	6558	6702	6848	6995	7144	7295	7447	7600	775
5					6708							
514					6714							
6	6151	6291	6433	6576	6720	6866	7014	7163	7314	7466	7620	777
61/2	6157	6297	6438	6582	6726	6872	7020	7169	7320	7472	7626	778
7					6732							
714					6738							
8					6744							
81/2	6180	8320	6462	6606	6750	6897	7045	7194	7345	7498	7652	780
9′-					6756							
914					6762							
·10	6198	6338	6480	6624	6769	6915	7063	7213	7364	7517	7672	782
1014					6775							
îĭ					6781							
111/2					6787							
/2	10210	5550	U, X D O	0012	0.00	0000	. 002	. 202	• 000	. 000	. 001	785

¹G. H. CLEVENGER, et al., "Pulp Constants," Eng. and Min. Jour., Dec. 19, 1914.

OPERATING DATA ON DORR THICKENERS1

Mill	Sq. ft. settling area per ton of solids thickened per 24 hr.	Sq. ft. settling area per gallon overflowed per minute	Remarks
San Rafael, Mexico	4.5		Tube-mill product, 75 per cent. -200 mesh, discharge 45.5
Liberty Bell, Colorado.	15.0	12.6	per cent. solids. Tube-mill product, much light argillaceous slime. Discharge 33 per cent. solids: +100, 17 per cent.; +200, 13 per cent.; -200, 70 per cent. Feed 9:1. Solution fed at capacity; solids not. Large area per gallon overflowed per minute due to
Mogul, South Da- kota.	3.92		density of underflow and nature of the slime. Tube-mill product, ore siliceous: +60, 0.6 per cent.; +100, 7.8 per cent.; +200, 26 per cent.; -200, 65.6 per cent. Discharge 56 to 59 per cent. sol-
Batopilas, Mexico.	0.6 to 0.9		ids. Continuous decantation. 40-mesh product; 90 per cent.
Zambona, Mexico.	3.1		passing 100 mesh. Tube-mill product. Discharge
Dominion, Ontario	5.4		40 per cent. solids. Tube-mill product, 88 per cent200 mesh, ore diabase. Discharge 40 per cent. solids. Feed 6:1.
Porcupine-Crown, Ontario.	4.25		Tube-mill product, 75 per cent. -200 mesh. Discharge 65 per cent. solids. Quarts ore. Continuous decantation. With 5.1 sq. ft. settling area per ton settles to 71 to 73 per cent. solids.
El Palmarito, Mexico.	4.5		Tube-mill product: pure quart- zite, 97 per cent200 mesh. Feed 7:1. Discharge 65 to 70 per cent. solids. Continuous
Amparo, Jalisco, Mex.	4.9	1.4	decantation. Tube-mill product, siliceous: 93.5 per cent. — 200 mesh. Feed 24.5:1. Discharge 23.5 per cent. solids; used to feed
Veta, Colorado, Parral, Mex.	5.0	31/34	vanners. Tube-mill product, rather argillaceous: 71 per cent. — 200 mesh. Feed 11:1. Discharge 33 per cent. solids for agitator. Have settled to 65 per cent.
Smuggler-Union, Telluride, Colo.	•••••		solids. Very clayey slime with classified sand. Screen test: +40, 1.48 per cent.; +60, 7.27 per cent.

¹ Metallurgical and Chemical Engineering, February, 1915. a. Not up to capacity of overflow.

OPERATING DATA ON DORR THICKENERS. Continued

Mill	Sq. ft. settling ares per ton of solids thickened per 24 hr.	Sq. ft. settling area per gallon overflowed per minute	Remarks
Smuggler-Union, Telluride, Colo.			+100, 14.81 per cent.; +200, 11.63 per cent.; -200, 65.81 per cent.
	30.0	26.0	Settling from cold water, slightly alkaline. Feed 8:1. Discharge 50 per cent. solids.
	10.0		1.429 sp. gr. Settling from cyanide solution. Feed, 2.5:1. Discharge 40 per cent. solids, 1.316 sp. gr.
A large copper company, Arisona.	11.6	8.11	Considerable argillaceous slime. Feed 10.4 per cent. solids. Discharge 25.3 per cent. solids.
Pennsylvania Steel, Lebanon, Pa.	14.2	2.48	Thickening ahead of vanner concentration. Feed 2.8 per cent. solids. Discharge 10.6 per cent. solids. Overflow 0.4 per cent. solids, extremely fine, which does not interfere with using water again.
Nevada Consolidated, Ely, Nev.		1.25	"Each 17-ft. thickener supplies wash water for 20 Wilfley tables and occasionally for wash on vanners. One thickener has a greater capacity than twelve 8-ft. cones." Area of 17-ft. tank is 226 sq. ft.; of the twelve 8-ft. cones, 525 sq. ft.
Broken Hill, Proprietory, Australia.	• • • • • • • • • • • • • • • • • • • •	1.80	Dewatering slime from lead- zinc concentration mill. Feed 100:1. Discharge 55 per cent. solids.
Anaconda Copper, Mont.		5.95	Dewatering slime from concentrator. Forty 4-deck thickeners, each 28 ft. in diameter by 3 ft. 3 in. deep, handle about 26,000,000 gal. of pulp per day which contains approximately 2 per cent. solids. A clear overflow obtained, the underflow containing about 15 per cent. solids, which is fed to buddles.

The data given here show that when pulp is carried in cyanide solution a provision of 5 to 6 sq. ft. per ton for a siliceous tube mill product is ample and from 7 to 15 sq. ft. for a clayey material or classified slime product. When very dilute products are handled the area required is determined usually by the gallons per minute to be overflowed.

Power Details for Pachuca Tanks¹

Tank, diam. × ht., feet	Ore	Charge tons	Free air, cu. ft.	Pressure, lb. per sq. in.	Horse- power	Pulp
7.5×37 7.5×37 10×40 13×55 10×40 7.5×37 10×40 13×55	Slime	15 40 35 110 50	5 17 9 16 25 14 22 38	22 26 22 33 22 22 23 35	0.5 2.0 0.75 1.75 2.25 1.4 2.3 4.0	Thin. Thin. Thin. Thin. Thin. Thickened. Thickened. Thickened.

This estimation of horsepower required conforms to the popular ideas on that point. On the basis of some careful tests which have been made, however, it is probable that actual power consumption is considerably higher.

Principles of Cyanidation

The cyanide process is based upon the solubility of gold and silver, and of some of the compounds of both metals, in an alkaline cyanide. The chemical theory is expressed in Elsner's equation, which was first brought forward by him to show the action of oxygen in the dissolution of precious metals. It is as follows:

$$2Au + 4KCN + O + H_2O = 2KAu(CN)_2 + 2KOH.$$

The usual cyanide salt was formerly potassium cyanide, but for reasons of economy, the sodium salt is principally used at the present time. The commercial product contains about 125 to 128 per cent. of the required compound in terms of KCN.

The essential difference between gold and silver cyanidation is that the gold is almost universally present as a free metal, and the cyanide dissolves the gold only. On the contrary, silver is seldom present in the free state, and usually occurs as a sulphide, chloride, or bromide. The sulphide is the most rebellious of all the compounds, except those which contain highly complex mixtures of antimony, arsenic, cobalt and nickel, but all of these can be treated. Silver sulphide often goes into solution as a sulphide, and it requires some manipulation to separate the silver as a metal.

The consumption of cyanide varies from as low as 0.1 lb. per ton of ore treated, in the case of fine free gold disseminated in pure quartz with no cyanicide, to as much as 5 or 6 lb. per ton in the case of semi-rebellious silver ores. Of course the limit of cyanide consumption depends entirely upon the richness of the ore to be treated. A rich ore will stand a higher consumption than a poor ore. Under ordinary commercial conditions, however, about 5 or 6 lb. per ton would be the limit on ore no matter how high its grade, since the consumption of much more cyanide than this would throw the cost up into competition with the smelting processes, under which circumstances smelting would be preferable to cyanide treatment.

¹ Eng. and Min. Journ., Vol. LXXXVI, 1908, p. 901.

SECTION VIII FUELS AND REFRACTORIES

CALORIFIC AND EVAPORATIVE VALUES OF VARIOUS LIQUID FUELS¹

	Sp. gr.	Flash point, °F.	Calorific value by bomb calories	Actual evapora- tion from and at 212°F.
American residuum	0.886	350	10,904	15.0
Russian Astatki	0.956	308	10,800	14.8
Texas	0.945	244	10,700	14.79
Burma	0.920	230	10,480	14.5
Borneo	0.936	285	10,461	14.0
Mexican crude	0.950	290	10,500	14.90
Oklahoma	0.863		10,800	
Roumanian residue	0.946		10,500	
Trinidad crude	0.945		10,200	
California	0.962		10,400	
Shale oil	0.875	288	10,120	13.8
	0.979	206	_ / _	12.0
Blast furnace oil		1	8,933	
Heavy tar oil	1.084	218	8,916	12.0
Gasoline	0.7100		11,733	
Ohio crude	0.8048		11,149	

¹ Specially compiled for "The Petroleum Year Book, 1914."

BAUMÉ GRAVITY AND CORRESPONDING SPECIFIC GRAVITIES, WEIGHTS PER GALLON AND CALORIFIC POWER OF OIL1

,,		,			
Baumé°	Specific gravity	Pounds in a gallon	Calculated B.t.u. per pound	Calculated B.t.u. per gallon	Remarks
14 15 16 17 18 19 20 21 22 23 24	0.9722 0.9655 0.9589 0.9523 0.9459 0.9395 0.9333 0.9271 0.9210 0.9150 0.9090	8.10 8.05 7.99 7.94 7.88 7.83 7.78 7.68 7.68 7.63 7.58	18,810 18,850 18,890 18,930 18,970 19,010 19,050 19,050 19,130 19,170 19,210	152,361 151,743 150,931 150,304 149,484 148,848 148,209 147,506 146,918 146,267 145,612	Mexico, California, Texas and Kansas crudes, fuel oil
25 26 27 28 29 30 31 32 33 34 35	0.9032 0.8974 0.8917 0.8860 0.8805 0.8750 0.8695 0.8641 0.8588 0.8536 0.8484	7.54 7.49 7.44 7.39 7.34 7.29 7.25 7.21 7.16 7.12 7.07	19,250 19,290 19,330 19,370 19,410 19,450 19,450 19,530 19,570 19,610 19,650	145,145 144,482 143,815 143,144 142,469 141,790 141,303 140,811 140,121 139,623 138,926	Kansas, Indian Territory and Illinois crudes, Penn'a. fuel, California refined fuel
36 37 38 39 40 41 42 43 44 45	0.8433 0.8383 0.8333 0.8284 0.8235 0.8187 0.8139 0.8092 0.8045 0.8000	7.03 6.99 6.95 6.91 6.87 6.83 6.80 6.76 6.72 6.68	19,690 19,730 19,770 19,810 19,850 19,850 19,930 19,930 19,970 20,010 20,050	138,421 137,913 137,402 136,887 136,370 135,849 135,524 134,997 134,467 133,934	Ohio, Penn'a. and West Virginia crude, Cali- fornia and Kansas refined fuel oil
46 47 48 49 50	0.7954 0.7909 0.7865 0.7821 0.7777	6.64 6.60 6.57 6.53 6.49	20,090 20,130 20,170 20,210 20,250	133,398 132,858 132,517 131,971 131,423	Kerosene and gasoline

¹ From "Fuel Oil Data," TATE-JONES & Co., Inc., furnace engineers, based on Sherman and Krapff's formula:

B.t.u. = 18,650 + 40 (Bé.° - 10)

Journ. Am. Chem. Soc., October, 1908.

١

STATES 1
UNITED
ANALYBES—1
FUEL
P.O
LIMITS

	H20	Ash	Sulphur	٠ ٥ _.	н	N + 0	Calories
Peat. Brown coal. Bituminous. Anthracite. Coke*	6.00-19.7 5.8 -14.0 0.6 - 5.2 0.5 - 2.5 0.15-1.2	3.2-36.0 1.7-14.7 6.1-14.7 1.0- ? 3.8-11.5	0.19-1.94 0.63-2.20 0.90-4.5	53-70 60.5-78.8 91-98 87-93	3.6-7.4 4.8-5.2 0.0-3.0 0.4-3.0	10.8-23.9 9.1-15.4 0.0-3.0	2867–5161 4700–6000 6000–8000 7000

These values from private notes on Eastern cokes. ¹ Somermeren's "Coal." ² Compressive strength of 600–2000 lb. per square inch, hardness of 2.5–3.

	L	TYPICAL GAS ANALYSES1	ALYSES ¹	1	
	00	Vol. hyd. earb.	N	5 00	Н
Producer gas. Mond gas. Iron-furnace gas. Water gas (blow up). Water gas (true).	23.7-33.6 10.3-11.0 20.0-32.0 23.7-32.2 40.9-45.2 0.6-1.8	1.3 - 11.9 $2.0 - 5.3$ $0.0 - 0.6$ $0.18 - 0.44$ $0.2 - 1.1$ $28.5 - 77.3$	49.5-67.1 43.0-55.8 55.0-65.0 63.9-65.9 1.9-7.1	0.45-5.30 14.6-16.5 6.0-18.0 1.6-7.0 1.8-5.6 1.3	1.25-9.7 ² 23.5-27.5 1.0-6.0 2.1-2.95 44.8-51.4 18.9-68.5

1 Hofman's "General Metallurgy."
2 Using steam.

OXYGEN AND AIR REQUIRED FOR PERFECT COMBUSTION¹

	Requires	kilograms	Product	of combustion	Nitrogen in original
1 kilogram	Oxygen	Dry air	Composi- tion	Kilograms	sir kilograms
C CO H CH ₄ Fe Fe Si P Mn	1.333 2.667 0.571 8.000 4.000 3.429 0.286 0.429 1.143 1.290 0.291	5.777 11.555 2.472 34.664 17.332 14.848 1.238 1.857 5.064 5.586 1.221	CO CO ₂ CO ₂ H ₂ O CO ₂ , H ₂ O FeO Fe ₂ O ₃ SiO ₂ P ₂ O ₅ MnO	2.333 3.667 1.571 9.000 2.750, 2.250 3.143, 1.286 1.286 1.439 2.143 2.290 1.291	4.444 8.888 1.901 26.664 13.332 11.419 0.952 1.428 3.921 4.296 0.969
S	1.000	4.333	SO ₂	2.000	3.333

Theoretical Maximum Combustion Temperatures²

Oxyhydrogen flame	3191°C.
Hydrogen and dry air	2010°C.
Hydrogen and dry air in 25 per cent. excess	1764°C.
Carbon monoxide with cold air	2050°C.
CO and air, both at 700°C	2284°C.
Natural gas and air	
Natural gas with air at 1000°C	2288°C.
Thermit $(2Al + Fe_2O_3)$	2694°C.

COMPARATIVE COMPOSITION OF DIFFERENT FUELS⁸ Moisture Content when New

Fuel	Moisture, per cent.	Remarks
Wood	30-60 50-90 30-45 2-25 1- 5 1- 3	Green wood. As dug. As mined. As mined. As mined. As mined.

From Hofman's "General Metallurgy."

J. W. Richard's "Metallurgical Calculations," Vol. I, pp. 36-39.

SOMERMEIER'S "Coal."

Composition and Heating Value of Air-dried Materials

		£	en eş	Bitur	ninous	rgh	44	
	Wood	Pest ¹ Florida	Lignite, ? North Dakota	Illinois?	Ohio, 3 Hock- ing	Penna.,4 Pittsburgh	Semi-bit., ² New River	Anthracite, 2 Penna
Proximate Moisture Volatile Fixed carbon Ash	. .		37.10 39.49	32.68 47.46	39.00 50.50	35.00 57.85	20.54 73.61	7.27 74.32
Ultimate Carbon Hydrogen Nitrogen Oxygen Sulphur Ash	40.0 7.2 0.8 50.7	100.00 46.57 6.51 2.33 38.97 5.17 0.45	55.16 5.61 0.91 30.98 0.63	60.51 4.88 1.23 14.20 4.45	1.30 11.95 3.35	78.75 5.14 1.55 7.56 0.90	82.41 4.38 1.05 5.87 1.20	75.21 2.81 0.80 4.08 0.77
Determined Calorific value Calculated Calorific value	100.0 4200	100.00 4515 4338	5273 5071	100.00 6199 6059	100.00 7155 7100	7865 7845	100.00 8254 7942	6929 6886

ULTIMATE COMPOSITION OF CRUDE OILS AND COAL¹ CRUDE OIL

	Sp. gr.	C	н	0
Pennsylvania Russia (Balachny) Russia (Balachny re-	0.886 0.884	84.9 87.4	13.7 12.5	1.4
siduum) Borneo Texas Burma	0.928 0.945 0.936 0.920	87.1 87.8 85.66 86.4	11.7 10.78 11.03 12.1	1.2 1.24 3.31 1.5

¹ From "The Petroleum Year Book, 1914."

U. S. G. S., "Bulletin No. 332."
 U. S. G. S., "Professional Paper, No. 48."
 Ohio G. S., "Bulletin No. 9."
 U. S. G. S., "Bulletin No. 290."

Mineral Oils—General Composition¹

The characteristics of crude mineral oils and their products vary greatly in different localities; but the following general information may be of interest.

	Gravity, deg. Bé.	Flash point, deg. F.	Burning point, deg. F.
Crude oil	· •	110-200 90-125 100-250 100-300 125-500	120-220 105-150 110-325 125-375 200-600

The heat value of mineral oils and their products may be very closely determined from their gravity, by the following formula:

B.t.u. per pound = $18,650 + \{40(Baumé - 10)\}$ (SHERMAN AND KRAPFF)

(n.	A	Ŧ	2
•	/E D	А	1.	_

			<u> </u>				·
	Sp. gr.	C	H	О	ន	Ash	H ₂ O
Welsh Newcastle Lancashire	1.256	82.1		1.0 1.3 1.3	1.4 1.2 1.4	4.1 5.7 9.5	4.9 3.8 4.6

COMMERCIAL SIZES OF ANTHRACITE

	Sise of screen, inc		Wt. per	1 cu. ft.
Grade	On	Through	cu. ft., lb.	solid coal gives, cu. ft
Lump Broken Egg Large stove Small stove Chestnut Pea No. 1 Buckwheat No. 2 Buckwheat	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	57.0 53.0 52.0 51.5 51.25 51.00 50.75 50.75	1.614 1.755 1.769 1.787 1.795 1.804 1.813 1.813

Shale Oil

These oils are secured by the distillation of shales. typical shale analyses are given by Sexton as follows:

¹ "The Diesel Engine," Busch-Sulzer Bros., Diesel Engine Co. ² "Petroleum Year Book," 1914.

Volatile matter, 34.96 per cent.; fixed carbon, 7.54 per cent.; ash, 57.5 per cent. (2) Volatile matter, 13.5 per cent.; fixed carbon, 2.5 per cent.; ash, 84 per cent.

Typical Gas Analyses ¹ (1	BY \	VOLUME)
--------------------------------------	------	---------

<u></u>	Natural gas Ohio	Coal gas	Producer gas	Water gas	Mond gas
Hydrogen	1.89 0.2 92.84 0.35 3.82 0.75	51.8 9.1 31.8 5.2 2.1	$8.0 \\ 23.7 \\ 2.2 \\ 61.5 \\ 4.1$	49.17 43.75 0.31 4.00 2.71	27.2 11.0 1.8 0.4 42.5 17.1

KINDLING TEMPERATURES OF FUELS²

Solid	Deg. C.	Gaseous	Oxygen	Air
Dry peat	. 700 200–400	Hydrogen Carbon monoxide, moist. Ethylene. Acetylene. Hydrogen sulphide. Methane. Ethane. Benzene. Illuminating gas. Water gas. Enriched producer gas. Propane. Propylene. Cyanogen.	543 429 364 650-750 520-630 547 504	406-440 580-590 644-658

Calorific Power of Fuels

Let H represent the percentage of hydrogen in a fuel; C represent the percentage of carbon; O the oxygen; S the sulphur; and assume also that the water formed by the combustion, represented by H_2O , does not condense (which it usually does not in metallurgical operations).

Dulong's formula for calorific power of a fuel then is:

$$C.P. = \frac{8,100C + 34,500(H - \frac{O}{8}) + 2,250S - 537H_2O}{100}$$

An empirical formula adopted by German engineers is:

$$C.P. = \frac{8,100C + 29,000(H - \frac{O}{8}) + 2,500S - 600H_2O}{100}$$

¹SEXTON, "Fuel and Refractory Materials."

² Dixon and Coward, "Journ. Chem. Soc. of London," 1910, p. 514.

FRACTIONS OF AVERAGE COAL TAR AND THEIR USES!

TRACTIONS	OF AVERAGE	COAL TAR	AND THEIR	Cara-
First crude separation by distillation.	Light oil.	Middle oil (or dead oil).	Heavy oil (including anthracene	Pitch.
Temperatures of distillation. Percentage in	70°-160°C.	160°-230°C. 8	oil). 230°–360°C. 24	Above 360°C. 65
tar. Intermediate products, by distillation or expression.	Benzene, tolu- ene, xylene, etc.; phenol.	Phenol, cresols, etc.; naphtha- lene, heavy hydrocarbons	phthalene, anthracene;	Soft pitch, hard pitch.
Crude commer- cial products and their uses.	"Bensol" and solvent naphtha for solvents, paint thinners, motor fuel, gas enrichment.	Lamp	te oil. black. Road oils, im- pregnation of timber. Roofi	Pitch, briqueting, protective paints. ng tars. g tars.
Intermediate chemical prod- ucts.	Nitrobenzene, aniline salts, aniline oil, carbolic acid.	Carbolic acid, picric acid, phthalic acid, naphthols, naphthyla-mines, salicylic acid.	Anthraquin- one, ali- sarin.	9 was 5.
Refined chemical products, dyes, etc., and their uses.	Nitrotoluenes, diphenylamine and other ingredients of explosives; aniline dyes; hydroquinone and other photographic developers; drugs and medicines.	Picric acid, pic-	·	

Inflammability of Gaseous Mixtures—Determination of the Dilution Limits.2—The results given by previous workers varied over a considerable range. The authors define a gaseous mixture as inflammable at a stated temperature and pressure if it will propagate flame indefinitely when the unburnt portion of the mixture is kept at that temperature and pressure. Combustion in an inflammable mixture is not necessarily complete. In order to conform to this definition, the flame is started near the bottom of a tall vessel which is of sufficient cross-section to minimize the cooling influence of the walls, and the bottom of the vessel is sealed in water so that the pressure cannot rise appreciably. Upward flame propagation is adopted since in very weak mixtures the velocity of propagation may be less than that of the upward convection currents and downward propagation of the flame may thus be prevented. Under these conditions the following minima were found:

¹ Tech. Paper 89, Bureau of Mines.

² H. F. Coward and F. Brinsley, Chem. Soc. Trans., 1914, 105, 1859-1885.

Lowest Limits for Hydrogen, Methane and Carbon Monoxide in Air.—Mixtures at atmospheric pressure, and saturated with water vapor at 17°-18°C., were inflammable if they contained not less than 4.1 per cent. H₂, 5.3 per cent. CH₄, or 12.5 per cent. CO.

Composition of the Residual Atmosphere Produced by FLAMES¹

	Composition which	on of residual at flame was extin	mosphere in guished
Substance burnt	O ₂ , per cent.	N ₂ , per cent.	CO ₂ , per cent.
Alcohol	14.9	80.7	4.35
Methylated spirit	15.6	80.2	4.15
Paraffin oil	16.6	80.4	3.0
Colza and paraffin	16.4	80.5	3.1
Candles	15.7	81.1	3.2
Hydrogen	5.5	94.5	
Carbon monoxide	13.4	74.4	12.2
Methane'	15.6	82.1	2.3
Coal gas	11.4	83.7	4.9

LIMITS OF COMBUSTION (GAS AND AIR)2

Lower explosive limit, per cent.	Other authors	Upper explosive limit, per cent.	Other authors
16.00	13-16.7	74.95	74.1-77.55
B	4.5-10	66.40	55-805
		66.75	
		52.30	$52.3 - 80^{5}$
	4.5-8.1	19.10	18.4-305
1	4-7.7	12.80	12.8-16.75
2.40	1.626	4.90	6.0^{6}
	3.5-4.1	14.6	11.8-225
91	4.4-13		91-96.75
	plosive limit, per cent.* 16.00 9.45 12.40 3.35 7.90 6.10 2.40 4.10	plosive limit, per cent.* 16.00	plosive limit, per cent.* Other authors plosive limit, per cent.* 16.00 13-16.7 74.95 9.45 4.5-10 66.40 12.40 66.75 3.35 2.8-3.35 52.30 7.90 4.5-8.1 19.10 6.10 4-7.7 12.80 2.40 1.626 4.90 4.10 3.5-4.1 14.6

Coal Burned per Square Foot of Grate in Reverberatory Furnaces⁷

Hand reverberatory roasting furnace	3 to	8 lb.
Agglomerating or lead-reverberatory smelting furnace	19 +0	16 lh
Copper-reverberatory smelting furnace	16 to	30 lb.

Journ. Soc. Chem. Ind., Feb. 27, 1915.
 From Benson's "Industrial Chemistry." The Macmillan Co.

^{*} Eitner's values.

With oxygen.

It is evident that the various observers have not standardized conditions.

Bureau of Mines, 1915. Probably most reliable figures given.

GRÜNER, "Traité de Metallurgie Générale."

438 METALLURGISTS AND CHEMISTS' HANDBOOK

Puddling furnace 20 to 30 lb. Heating furnace 30 to 40 lb. Locomotive boilers (induced draft) 80 to 100 lb.
Ratio of Areas of Total Grate to Air Space ¹
Coke 3:1 to 2:1 Bituminous coal. 3:3:1 to 2:1 Brown coal. 5:1 to 3:1 Peat or wood. 7:1 to 5:1
Combustion Data
Good modern practice
1 lb. coal average 13,500 B.t.u. 1 lb. coal $(13,500 \times 778) + (60 \times 33,000)$ 5.3 hphours.
Lost through grates
Lost chimney gases. 22.00 per cent. Lost main pipes radiation. 1.56 per cent.

t engine radiationt engine exhaust	2.08 per cent. 57.31 per cent.
Total loss	90.57 per cent.

0.22 per cent.

... 1.40 per cent.

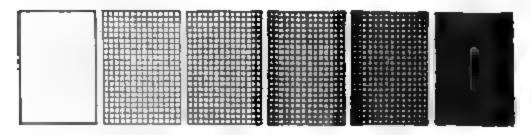
Ringelmann's Smoke Chart

Lost auxiliary pipes radiation

Lost auxiliary exhaust.....

Lost engine radiation.....

The following chart is convenient for estimating the density of smoke from chimneys, both as a check on the completeness of combustion and as evidence in case certain chimneys are attacked as nuisances by owners of property near metallurgical



plants. (Use this chart at arms length. The original is a chart 3×24 in., supposed to be posted about 50 ft. away.)

Leitfader to Eisenhüttenkunde, 1898, p. 104.

```
Standard Fire Brick Shapes<sup>1</sup>
       Name
                                 Dimensions
                            9 \times 4\frac{1}{2} \times 2\frac{1}{2}
9 in.
                            9 \times 2\frac{1}{2} \times 2\frac{1}{4}

9 \times 4\frac{1}{2} \times 1\frac{1}{4}

9 \times 4\frac{1}{2} \times 2

0 \times 6\frac{3}{2} \times 2\frac{1}{4}
Soap
No. 1 Split
No. 2 Split
                            9 \times 6 4 \times 2 4
9-in. large
                            9 \times 3\frac{1}{2} \times 2\frac{1}{2}
9-in. small
                            9 \times 4\frac{1}{2} - 4 \times 2\frac{1}{2}: 12 ft. diam. inside. 112
No. 1 Key
                                   brick to circle.
                            9 \times 4\frac{1}{2} - 3\frac{1}{2} \times 2\frac{1}{2}: 6 ft. diam. inside.
No. 2 Key
                                     brick to a circle.
                            9 \times 4\frac{1}{2} - 3 \times 2\frac{1}{2} : 3 ft. diam. inside.
No. 3 Key
                                          brick to a circle.
                            9 \times 4\frac{1}{2} - 2\frac{1}{4} \times 2\frac{1}{2}: 18 in.
No. 4 Key
                                     diam. inside. 26 brick to
                                     a circle.
                            9 \times 4\frac{1}{2} \times 2\frac{1}{2} - 2: 5 ft. diam. inside.
No. 1 Wedge<sup>2</sup>
                                                                                                102
                                     brick to a circle.
No. 2 Wedge<sup>2</sup>
                            9 \times 4\frac{1}{2} \times 2\frac{1}{2} - 1\frac{1}{2}: 2 ft. 6 in.
                                   diam. inside. 63 brick to a
                                   circle.
                            9 \times 4\frac{1}{2} \times 2\frac{1}{2} - 2:4 ft. diam. inside. 72 brick to a circle.
No. 1 Arch
                            9 \times 4\frac{1}{2} \times 2\frac{1}{2} - 1\frac{1}{2}: 2ft. diam.
No. 2 Arch
                                                   42 brick
                                   inside.
                                                                       to
                                   circle.
                            9 \times 4\frac{1}{2} \times 2\frac{1}{2} - 1: 6 in. diam. inside.
No. 3 Arch
                                                                                                  19
                                     brick to a circle.
Side Skew
                            9 \times 4\frac{1}{2} - 1\frac{3}{4} \times 2\frac{1}{2}
End Skew
                            9 \times 7 \times 4\frac{1}{2} \times 2\frac{1}{2}
                            9 \times 4\frac{1}{2} - 1\frac{1}{2} \times 2\frac{1}{2}
Skewback
                            9-4\frac{1}{2}\times4\frac{1}{2}\times2\frac{1}{2}
No. 1 Neck
No. 2 Neck
                            9-2\times 4\frac{1}{2}\times 2\frac{1}{2}
No. 3 Neck<sup>2</sup>
                            9 \times 4\frac{1}{2} \times 2\frac{1}{2} -
                            9 \times 4\frac{1}{2} \times 2\frac{1}{2} - \frac{1}{8}
Feather edge
                            9 × 4½ × 2½ (rounded corner).

9 × 4½ × 2½ (rounded corner and beveled corner).
No. 1 Jamb
No. 2 Jamb
No. 3 Jamb
                            9 \times 4\frac{1}{2} \times 2\frac{1}{2} (rounded corner).
No. 3 Bullhead<sup>2</sup> 9 \times 4 \times 3 - 2 (see illustration).
                            9 \times 3 \times 3 or 9 \times 2\frac{3}{4} \times 2\frac{3}{4}.
Checker
Large 9 in.
No. 1 Wedge
                            9 \times 6\% \times 1\% : 5 ft. diam.
                                   inside. 102 brick to the circle.
Large 9-in.
                            9 \times 6\% \times 2\% - 1\% : 2 ft. 6
No. 2 Wedge
                                                                                     in. diam.
                                   inside. 63 brick to the circle.
                            9 \times 4\frac{1}{2} - 3 \times 2\frac{1}{2}
Edge arch
                           18 (or 20 or 24) \times 6 \times 3.
Checker tile
Checker tile (mill tile) 18 (or 20 or 24) \times 9 \times 3.
   As made by the Stowe-Fuller Co., Cleveland, Ohio. Other makers deviate
```

slightly from the figures given for keys.

The wedge brick taper from end to end, as do the keys, No. 3 neck, and bullhead.

		[atoT	23 25 25 25 25 25 25 25 25 25 25 25 25 25	
	key bricks	Straights	,	
	n. key l	No. 1 wedge		
	13 1 -in.	No. 2 wedge		
		latoT		
	ks	.ai-8		
E81	ge bricks	No. 1 wedge		
CIRCLES 1	Wedge	No. 2 wedge	00488444 00888444	
ARIOUS		[stoT	288844455555555555555555555555555555555	
^		.ni-8	4007404	
CK FOR	bricks	No. 1 key		
Firebric	key	No. 2 key		
of Fu	9-in.	No. 3 key	. ಬಿಸುಹಬ್ಬರಬಹಿ	
TABLE		No. 4 key	NH 0	
T		IstoT	.4000000000000000000000000000000000000	
	ks	.ai 8		
	Arch bricks	No. 1 arch		F. 11.
	A 1	No. 2 arch	80	*ho 840
		Inside diameter of circle	7:12/26644466667666060606060606060606060606060	1 Prom

¹ From the Stowe-Fuller Co.'s catalog.

Hints on Brick Laying

One ton of fire-clay ought to lay about 6000 brick. The composition in which they are laid should be, if possible, of the same composition as the brick themselves, and the brick should be dipped in a thin paste and laid, not laid in a mortar. In general, the thinner the bond between the bricks the better the work. The joints are the zones of greatest weakness and are soonest attacked. For metallurgical furnaces it appears that the denser the brick the less its absorption. Magnesite brick are best laid in a suspension of finely ground magnesite in anhydrous tar, or magnesite and linseed oil, or in a suspension of mágnesite in a 20 per cent. sodium silicate solution. brick are best laid in a thin paste of 60 fine sand, 40 fire-clay. About 5/32 in. per foot should be left for expansion in a furnace bottom.

Always store Refractories in a Dry Place

Magnesite bricks are good conductors of heat, and where this conductivity would injure the armoring of the furnace, the brick should be backed by asbestos or some other non-conduc-Great variations of temperature, or heating when they are moistened with water or oil, will cause spalling. Magnesite brick should not be subjected to great loads when hot. For red-brick work 9 cu. ft. of sand and 3 bu. of lime will lay

1000 brick.

Brickwork Table¹

1 sq. ft. of 4½-in. wall requires seven bricks.

1 sq. ft. of 13½-in. wall requires twenty-one bricks. 1 cu. ft. of brickwork requires seventeen 9-in. bricks.

1 cu. ft. of fire-clay brickwork weighs 150 lb.

1 cu. ft. of silica brickwork weighs 130 lb.

1000 bricks (closely stacked) occupy 56 cu. ft.

- 1000 bricks (loosely stacked) occupy 72 cu. ft.
- M. S. Wologdine has probably done the best work on the thermal properties of fire brick. A. L. QUENEAU deduces, among others, the following conclusions from Wologdine's work:
- 1. All terra cotta, building bricks and fire bricks have practically equal coefficients of heat conductivity. The coefficients are differentiated in this class of refractory materials solely by the temperature of burning and not by the character of the clays or by their chemical composition.

2. In all refractory materials, including the special bricks, such as chrome, magnesia, carborundum and graphite, the heat conductivity is a direct function of the temperature of burning.

3. The coefficient of heat conductivity of chrome brick is

practically independent of the temperature.

4. There are remarkable variations in the permeability to gases of the same bricks with increase in temperature. one case the permeability changed from 3.3 liters per hour to

¹ HAVARD, "Furnaces and Refractories."

241 liters per hour. This shows the importance of scientifically selecting the clay mixtures for a given work as for crucibles or retorts where, as in zinc metallurgy, the permeability to gases has a material influence on the metal recovery. In this connection the nil permeability of graphite crucibles is to be noted. Perhaps the same results might be obtained at a much reduced cost by substituting clay flakes for the graphite flakes proposed by H. Putz (German pat. 198,840 of Sept. 29, 1907).

5. To secure efficient heat insulation, refractory materials should be burned at the lowest allowable temperature. This burning temperature is generally known; it is the maximum temperature to which the bricks will be exposed in the furnaces. The use of the maximum temperature is necessary in order to prevent the brick from shrinking any further when set in the furnace walls. Though this last fact is well known it is often neglected, and a shortening of the furnace life is the result.

6. The gas permeability of the bricks of blast-furnace linings must have an important bearing on their life, owing to the destructive action of carbon monoxide in contact with the iron

oxide present in the brick.

There is no question that the absorption of metals by a furnace bottom will be directly proportional to the air spaces in the original brick; consequently in work with any of the non-ferrous metals, the nearer the ratio of the specific gravity of the brick in bulk to the true specific gravity of the constituent material approaches unity, the better the brick.

Short Description of the Common Refractories

Alundum.—Melting point, 2050°C.; specific heat, 0.195-0.198 at 100°C.; thermal conductivity about twice that of fire brick. Electric resistivity, at 528°C., 130 megohms per cc.; at 730°, 16 megohms; at 892°, 5.3 megohms; at 1020°, 1.8 megohms. Coefficient of expansion, 0.0000071 per deg. C.; maximum crushing strength, 7½ tons per square inch; tensile strength, 1700 lb. per square inch. Specific gravity, 3.91.

Asbestos.—A very poor conductor of heat and refractory, but will not stand molten slags. The composition of a typical Canadian asbestos is: MgO, 40.07; FeO, 0.87; Al₂O₃, 3.67; SiO₂, 39.05, H₂O, 14.48; total 98.14%.

Bauxite.—Bauxite melts at 1820°C., but as bauxite shrinks about 30 per cent. and crumbles in calcining, some silica must be added to make a good brick. The washed bauxite is calcined at from 1350° to 1400°, ground, pugged with about 4 per cent. of a highly aluminous plastic clay, balled, dried and calcined. The mixture is then ground, pugged again with clay and hand molded. Basic open-hearth brick should not contain over 12 per cent. of silica. An analysis of an American bauxite brick is: SiO₂, 2 per cent.; TiO₂, 5 per cent.; Al₂O₃, 90.5 per cent.; Fe₂O₃, 1 per cent.; and CaO, 1.5-2 per cent. The crushing strength may be as high as 10,000 lb. per square inch, but in general the bricks are weak.

Bull Dog.—This is a mixture of ferric oxide and silica made by roasting tap cinder with free access of air. Tap cinder is a

basic ferrous silicate—2FeO·SiO₂ or thereabouts—and on roasting it takes up oxygen, and gives a mixture of ferric oxide and silica. As these do not unite, the substance is infusible in an oxidizing atmosphere, but fuses in a reducing atmosphere, ferrous silicate being re-formed.¹

Carbon brick—lay in a mixture of tar and carbon dust.

Chrome.—Typical chromites used for refractories analyze as follows (Eng. and Min. Journ., Oct. 24, 1908): Turkish: Cr_2O_3 , 51.70 per cent.; FeO, 14.20; Al_2O_3 , 14.10; MgO, 14.30; SiO_2 , 3.50; CaO, 1.70; H_2O , 0.30 per cent.; New Caledonian: Cr_2O_3 , 55.70 per cent.; FeO, 16.60; Al_2O_3 , 18.20; MgO, 9.80; SiO_2 , 0.25; CaO, 0.25; MnO, 0.20; P_2O_5 , 0.05; H_2O , 1.05 per cent.; Japanese: Cr_2O_3 , 44.55 per cent.; FeO, 15.25; SiO_2 , 5.4; CaO, 0.20; MgO, 19.10; Al_2O_3 , 15.20; H_2O , 0.30 per cent. Chrome is unreliable above 1500°C.

Conducts heat two to four times as well as clay brick. Makes a good breaking joint between magnesite and silica. Should be used as little as possible in furnace bottoms on lead, copper, silver, or gold work, as the cobbing is almost impossible either to grind or to smelt. It is not so strong as alumina, nor so

resistant to high temperatures.

Clay Brick.—Probably as fine a quality of clay brick is needed in the shafts of iron furnaces as anywhere. Two typical bricks for this purpose are given by Havard as follows: (1) Loss on ignition, 0.07; SiO₂, 54.44; Fe₂O₃, 2.53; Al₂O₃, 40.01; CaO, 0.18; MgO, 0.53; K₂O, 2.24. Crushing strength, pounds per square inch, side, 5098; edge, 3840; end, 2693. Specific gravity, true, 2.34; in mass, 2.03. Porosity, 12.93 per cent. of volume. Expansion, 0.042 in. per foot. (2) Loss on ignition, 0.07; SiO₂, 56.07; Fe₂O₃, 3.32; Al₂O₃, 39.00; CaO, 0.12; MgO, 0.18; K₂O, 1.30. Crushing strength, pounds per square inch, side, 5248; edge, 2170; end, 2710. Specific gravity, true, 2.43; in mass, 2.10. Porosity, 13.30 per cent. of volume. Expansion, 0.064 in. per foot.

Some Typical Refractories Analyses

·	Al ₂ O ₃	SiO2	Mgo	CaO	Fe ₃ O ₃	K ₂ O	Na ₂ O	Ti0;	Loss	Total
Briesen clay Saaran clay Striegau clay American fire brick Clay for open hearth	29.65 32.07	53.02 62.20	0.78 0.65	1.15 0.70	3.40 ² 4.01	0.55	••••	• • •	10.91	100.07 99.76 99.46
N. J. clay for zinc retorts	37.50	45.00	0.30	1.00	0.70	0.50	••••	1.5	13.50	

¹ SEXTON, "Fuel and Refractory Materials."

² FeO.

A general formula for determining how refractory a clay is is given by BISCHOF (cf. HAVARD'S "Furnaces and Refractories," p. 61). If Q be the refractory coefficient, a the oxygen content of the alumina, b that of the silica, and c that of the fluxes, then

$$Q = \frac{a^2}{bc}$$

If Q is between 2 and 4 the clay will make a third-grade fire brick; if between 4 and 6, a second-grade fire brick; from 6 to

14, a first-class fire brick.

Crystolon.—Crystallized silicon carbide (SiC)—does not fuse at 2700°C. Conducts heat a little better than alundum (q.v.). Electric resistivity, at 320°C., 31.8 megohms per cc.; at 650°C., 6.3 megohms; at 809°C., 3.2 megohms; at 940°C., 1.0 megohms; at 1040°C., 0.4 megohms. It is not affected by acids or acid vapors, except hydrofluoric, but reacts readily with alkalis, alkaline carbonates and alkaline sulphates, and, at elevated temperatures, with the oxides of practically all metals. Coefficient of expansion, 0.0000045 per deg. C.

Dinas brick—a classic English brick made in South Wales. Composition: SiO₂, 96.80 per cent.; Al₂O₃, 0.92; Fe₂O₃, 0.50; CaO, 1.20; alkalis, 0.20. It is essentially a silica brick with

lime as a binder. In America this is known as ganister.

Dolomite.—Analyses of typical dolomites (from Harbord's "Steel," p. 212) are: Raw, SiO₂, 1.10 per cent.; Fe₂O₃ and Al₂O₃, 1.64; CaO, 33.20; MgO, 19.60; CO₂, 44.30 per cent. Calcined, SiO₂, 3.66 per cent.; Fe₂O₃ and Al₂O₃, 4.80; CaO, 55.50; MgO, 34.83; CO₂, 1.06 per cent.

Fibrox—a fibrous silicon oxycarbide, formed in the presence of certain catalytic agents, of which calcium fluoride is one, by the reaction between vapors of silicon and carbon monoxide or dioxide. It is a soft, resilient, fibrous material, the average diameter of the fibers being stated by E. Weintraub of the General Electric Co. as being about 0.6μ , or about the wave

5		Therms	al ohms
Density	Temperature	R' in. cube	R cm. cube
0.231	200	950	2375
0.231	500	520	1300
0.412	200	1200	3000
0.412	500	605	1510
0.767	200	1320	3300
0.767	500	878	2195
1.27	200	1460	3650
1.27	500	987	2470
1.98	200	1590	3975
1.98	500	1000	2500

length of yellow light, or about one-twentieth that of fine cotton fiber. Its apparent weight is about 2½ to 3 grams per liter, its real specific gravity about 1.84 to 2.2. It is claimed to be the best heat insulator known. It oxidizes slowly above 1000°C.

The effect of the density on the heat resistivity of fibrox at temperatures of 200° and 500° is shown by the foregoing

table:1

Ganister—another classic English refractory. A typical analysis, from Harbord: SiO₂, 94.60 per cent.; Al₂O₃, 1.40; Fe₂O₃, 0.90; CaO, 0.48; MgO, 0.16; alkalis, 0.14; water, 2.60

per cent.

Lime.—FITZGERALD reports that lime fused in the electric furnace may be a very useful refractory. 'It is a better conductor of heat than ordinary lime. Blocks cut from it resist quick heating followed by sudden cooling. Fused lime resists exposure to moist air remarkably well, hydration being a matter of days.

Magnesite composition, Federal brick: SiO2, 1.46 per cent.; Al₂O₃, 1.50; Fe₂O₃, 7.58; CaO, 3.14; MgO, 86.36 per cent.

Conducts heat two to four times as fast as clay brick. Usually laid dry, or in a paste made of magnesite clay and 20 per cent. water-glass solution. Magnesite can only be considered "dead-burned" when the final ignition temperature exceeds 1800°C. The greatest objection to magnesite is its cracking when heated to a high temperature. This is due to its shrinkage; a piece of magnesite heated to 350° may have a density of

3.19, while electrically fused its density will be 3.65.

Silica Sand.—An analysis of the sand used for furnace bottoms in Swansea is (from Percy): SiO₂, 87.87 per cent.; Al₂O₃, 2.13; Fe₂O₃, 2.72; CaO, 3.79; MgO, 0.21; volatile, 2.60 per cent. Silica melts at 1750°, after softening at 1500° and becoming glassy at 1700°C. It expands on heating and does not return exactly to its former volume. In general, silica brick are highly refractory, porous, of low specific gravity, brittle and hard to cut, poor conductors of heat, inelastic, and not resistant to sudden changes of temperature. The compressive strength is about 1900 to 4000 lb. per square inch. A typical American silica-lime brick analyzed as follows: SiO2, 93.92 per cent.; Fe₂O₃, 0.79; Al₂O₃, 3.07; CaO, 2.55; MgO, 0.18; porosity, 18.58 per cent. of volume, expansion, 0.188 in. per foot. Another brick gave 0.346 in. per foot expansion.

Siloxicon—a more or less oxidized carborundum, the amorph-

ous crystolon of the Norton Co.

Zirconia—a pure white refractory of a density of about 5.0 and a melting point of about 3000°C. Its first important use was to replace the calcium-oxide cylinders in the Drummond Used also in the first Welsbach experiments. Its heatconducting power is not over half that of firebrick. Has been used as a lining of a SIEMENS-MARTIN furnace with good results.

¹ From a paper presented at the Atlantic City Meeting, American Electrochemical Society, Apr. 22, 1915.

REFRACTORIES

MELTING POINTS OF SOME REFRACTORY OXIDES!

Oxide	Temperature of volatilization	Melting point	Color of melt and sublimate	Furnace used	Remarks
Mago Caro Caro Caro Caro Caro Caro Caro Car	About 2000° 1690° 1750° 2000°	About 2400° 2800°(a) 2572°(a) 2080° About 2000° 2480°	White like porcelain Colorles, glassy Clear yellow melt White opaque melt	Cathode ray Both furnaces Cathode ray Cathode ray Cathode ray	Evaporated just before melting. Dissociated into its elements. Tendency for n.elt to orystallise. Dissociated, forming lower oxide. Evaporated just before melting
SnO		Did not melt Did not melt Did not melt	Black sublimate Transparent sublimate	Cathode ray Cathode ray Cathode ray	Dissociated, forming lower oxide.
Tho:	About 2000*	2000° Did not melt	White opaque sublimate	Cathode ray	Dissociated probably to VO-
VrO. Taro. Mao	Red heat Did not evaporate	Did not melt Did not melt 1650°	Blue-black sublimate Black	Cathode ray Cathode ray Cathode ray	Melt crystaliaed.

(*) According to C. W. Kanour, Jours. Franklin Inst., p. 587, 1913; other determinations according to Time and Binnersum, Zeil, anorg. Chom., 1914, p. 129.

Owing to its thermal conductivity a 2-in. lining of zirconia is equal to 4 in. of chamotte. It is practially unaffected except

by molten fluarides and bisilicates.

All binding materials tend to lower the melting point of zirconia. In lining furnaces or other metallurgical apparatus, natural zirconia can be mixed with anhydrous tar as a binder, in which case wooden forms are generally used. These are allowed to remain in place and consumed during the initial The temperature should be raised slowly at first, while burning out the tar, after which a temperature of at least 1400°C. must be maintained for about 48 hr. Natural zirconia begins to fuse at about 1800°C., and at about 2000°C. there is a noticeable volatilization of silica and other impurities.

In the manufacture of natural zirconia brick, muffles, crucibles, etc., about 2 per cent. of air-slacked lime as a binder has been used with success. In practice, a batch composed of 75 per cent. 100-mesh zirconia, 23 per cent. of 10 mesh, and 2 per cent. of slacked lime, is worked into a plastic with a 3 per cent. solution of 38°Bé. sodium silicate. The bricks or ware are then pressed from this and allowed to thoroughly dry in a warm atmosphere. The procedure from this point on is the same as in the burning of ordinary refractories, except that a temperature of at least 1400°C. is necessary to secure the proper

vitrification.

As the density of zirconia is rather high (about 5.0), it has been suggested where imperviousness is not desired, that the incorporation of certain organic substances or volatile salts

MELTING POINTS OF FIRE BRICK

 $2100^{\circ}(e)$, softens 1970° C.(e) Alumina 2050°C.(a) 1820°C.(b) Alundum Bauxite 1620-1785°C.(a) Bauxite brick 1865°C.(c) Bone-ash cupel Decomposes at 2220° with fusing.(b) Carborundum $2050^{\circ}\text{C.}(a)$; $2180^{\circ}(b)$; $1545^{\circ}-1730^{\circ}$.(c) Chromite 1555-1740°C.(a) Clay brick, 1st class Clay brick, 2d class 1400–1650°C.(e) Diatom nonpareil brick 900°C.(d) 1680°C.(c) Dinas silica 1740°C.(b) 1830°.(e) Kaolinite (pure) Softens about 2040°C.(e) Lime (CaO) 2720°C.(a), softens about 2500°C.(e) Magnesia 2165°C.(a), softens about 2000°C.(e) 1700–1705°C.(a) Magnesite brick Silica $2700^{\circ} + C.(a)$ Silicon carbide

⁽a) According to Bureau of Standards.
(b) Bull. Tech. A. et M., July, 1913, p. 728.
(c) W. H. PATTERSON, "Brit. Iron and Steel Inst. Carnegie Scholarship Memoirs," No. 6, p. 231, 1914.
(d) Information from manufacturers. An insulator, not a refractory.
(e) F. T. HAVARD, "Fuels and Refractories."

which would be destroyed during firing, thus producing small air cells, might serve to lighten the finished product without impairing its efficiency. Sawdust, cork dust or certain am-

monium salts might prove of value for such aëration.

Using pure zirconium oxide with 3 to 10 per cent. of magnesia, and using starch, phosphoric acid, glycerin or borates as binders very remarkable heat-resisting ware can be manufactured. The forms are dried for several days at a low temperature and then fired in the electric furnace at 2000–2300°C. Owing to the low coefficient of expansion this ware can be plunged red-hot into water without cracking.

Fused silica—thermal conductivity high. Melting point, 1430°C. Sp. gr., 2.5-2.6. Specific heat, 0.776. Coefficient of

expansion, 0.00000539 per deg. C.

Testing Refractory Materials under Load.—The melting point of various clays used in the manufacture of firebrick and retort material was found to be 200°-320°C. lower when the clay was under pressures of 54 to 112 lb. per square inch.

It should be remembered that it also often occurs that a very refractory material, as tested alongside Seger cones, will not stand up under a load. Thus, China clay tested by Dr. Mellor yields at 1410°C., but does not fuse until 1770°C., while fireclay bricks yielding under equal loads at 1435°C. fused at 1710°, and siliceous brick yielding at 1580°C., melted at 1750°C. In general the higher the silica content the greater the temperature

The following procedure is recommended in tentative tests submitted by the Committee on Refractories of the American Society for Testing Materials. A full-sized brick on end is heated under load under specified conditions and the resulting deformation measured. A furnace is described. It is heated by two tangentially disposed burners—gas or oil—the flames from which are separated from the brick by a cylinder of alun-The brick should be uniformly heated and its temperature measured by a thermo-couple, the junction of which is 1 in. from a face of the brick. Alternatively an optical pyrometer The brick rests on a highly refractory block, may be used. e.g., of carborundum, placed at the center of the furnace, and carries another block of the same material which projects through the top of the furnace. The load is applied to this block by means of a cross beam, supported on guide pillars and carrying weights attached at each end so as to apply a pressure on the brick of 25 lb. per sq. in. The specimen is heated to the test temperature in 4½ hours and maintained there for 11/2 Silica material is tested at 1500°C., high-grade clay goods at 1350°C., medium at 1300°C., and low-grade at 1100°C. The cooling is slow and lasts 5 hours at least. The length of the brick is measured to 0.02 inch before and after test.

Slag Penetration.—Tests involving the total immersion of a brick in a bath of molten slag did not give uniform results, besides requiring large and elaborate apparatus. The best results were obtained by studying the absorption of liquid slag

in a pocket drilled into one face of the brick. The drill was pointed at an angle of 150°, and cut a hole $2\frac{1}{2}$ in. in diameter, the depth at the side being $\frac{1}{2}$ in. The hole was cleaned out, and the brick, then heated to 1350° C. A known quantity of powdered slag was placed in the pocket, and after maintaining a temperature of 1350° C. for 2 hours, the brick was allowed to cool. When cold it was sawn in two, so as to bisect the original cavity at the center, thus exposing an area of penetration of the slag. This area was measured by means of a planimeter. Increasing the duration of the test above 2 hours had no great effect, neither had the fineness of the slag, although it was usually ground to pass a 40-mesh sieve. Increasing the quantity of slag taken did not markedly affect the area of penetration if corrected for the differing area of contact.

Crushing Test.—The brick to be tested is ground so that opposite faces are parallel, measured, and heated in a furnace to 1350°C. The time taken to heat up should be at least 6 hours, and the temperature of 1350°C. should be maintained for 2 hours. The brick is then quickly placed in position in a testing machine of standard type, with asbestos board above and below the specimen. The crushing weight is determined.

Brick for Rotary Cement Kilns.—While it might be supposed a basic brick would give the best results in cement kilns, according to W. Hamilton Patterson (British Iron & Steel Institute Carnegie Scholarship Memoirs, Vol. 6, 1914) an exceedingly satisfactory brick was: SiO₂, 73.2 per cent.; Al₂O₃, 18.3 per cent.; Fe₂O₃, 6.5; TiO₂, 0.4 per cent.; CaO, 0.4 per cent.; MgO, tr; alkalis, 0.50 per cent.; loss on ignition, 0.22 per cent. The melting point was 1735°C. His explanation of the success of such a brick is that it fuses on the surface and forms with a cement clinker a protective coating. The question of protective coatings may thus be an important one in judging firebrick.

Brick for Gas Retorts.—According to F. J. BYWATER (Journ. Gas Lighting, 1914, p. 899) silica retorts have recently been used in America with satisfactory results. The retorts were made from crushed ganister quartz (95 per cent. SiO₂), with 2 per cent. milk of lime as binding medium. They were of D-section, and were built up from bricks and tiles. The expansion on heating was ½ to ¾ 6 in. per foot, and was allowed for by making the joints either with thick paper or strawboard, which burned away leaving a thin carbon joint, or with cement consisting of mild aluminous clay, which shrank when heated. The mouthpiece ends of the retorts were made of solid moulded fireclay so as not to crack when cooled by the opening of the lid. The retorts were used with various types of hydraulic discharging machines. In some cases less carbon was formed on the inside of the silica retorts and the surface became glazed, facilitating discharge by pushers. The life of the retorts was 3½ to 4 years. The thermal conductivity was greater than with clay retorts, the fuel consumption was less, and the output greater owing to the shorter period required for burning off the charge.

450 METALLURGISTS AND CHEMISTS' HANDBOO

SEGER CONES AND THEIR SOFTENING TEMPERATURES¹

Estimated softening	Cone		Molecular composition				
point (deg. C.)	No.	Na ₂ O	РьО	Al ₂ O ₃	B ₂ O ₃	SiO ₂	
590	022	0.5	0.5		1	2.0	
620	021	0.5	0.5	0.1	1	2.2	
650	020	0.5	0.5	0.2	1	2.4	
680	019	0.5	0.5	0.3	1	2.6	
710	018	0.5	0.5	0.4	1	2.8	
740	017	0.5	0.5	0.5	1	3.0	
770	016	0.5	0.5	0.55	1	3.0	
800	015	0.5	0.5	0.6	1	3.2	
830	014	0.5	0.5	0.65	1	3.3	
860	013	0.5	0.5	0.7	1	3.4	
890	012	0.5	0.5	0.75	1	3.5	
920	011	0.5	0.5	0.8	1	3.6	

SEGER CONES AND THEIR SOFTENING TEMPERATURES¹

Estimated softening	Cone		1	Molecular	compositi	on	_
point (deg. C.)	No.	K ₂ O	CaO	Fe ₂ O ₃	Al ₂ O ₂	B ₂ O ₃	SiO ₂
950	010	0.3	0.7	0.2	0.3	0.50	3.50
970 990	09	$\begin{array}{c c} 0.3 \\ 0.3 \end{array}$	$0.7 \\ 0.7$	$\begin{bmatrix} 0.2 \\ 0.2 \end{bmatrix}$	$\begin{array}{c} 0.3 \\ 0.3 \end{array}$	0.45	3.50 3.60
1010	07	0.3	0.7	0.2	0.3	0.35	3.6
1030	06	0.3	0.7	0.2	0.3	0.30	3.70
1050	05	0.3	0.7	$0.\overline{2}$	0.3	0.25	3.7
1070	04	0.3	0.7	0.2	0.3	0.20	3.8
1090	03	0.3	0.7	0.2	0.3	0.15	3.8
1110	02	0.3	0.7	0.2	0.3	0.10	3.9
1130	01	0.3	0.7	0.2	0.3	0.05	3.9
1150	1	0.3	0.7	0.2	0.3	[4.0
1170	2 3	0.3	0.7	0.1	0.4	[]	4.0
1190	3	0.3	0.7	0.05	0.45	:	4.0
1210	4	0.3	0.7		0.5		4.0
1230	4 5 6	0.3	0.7		0.5		5.0
1250	0	0.3	0.7	• • • • •	0.6		6.0
1270	7	0.3	0.7] • • • • •	0.7		7.0
1290 1310	8 9	$\begin{array}{c} 0.3 \\ 0.3 \end{array}$	$\begin{array}{c c} 0.7 \\ 0.7 \end{array}$		0.8 0.9		8.0 9.0
1310	10	0.3	0.7		1.0		10.0
1990	10	0.5	0.7		1.0		10.0

¹ F. T. HAVARD, "Furnaces and Refractories."

SEGER CONES AND THEIR SOFTENING TEMPERATURES

Estimated	Cone		Molecular c	omposition	•
softening point (deg. C.)	No.	K ₂ O	CaO	Al ₂ O ₂	SiO ₂
1350	11	0.25	0.58	1	10.0
1370	12	0.21	0.50	1	10.0
1390	13	0.19	0.43	1	10.0
1410	14	0.17	0.39	1	10.0
1430	15	0.14	0.33	$\bar{1}$	10.0
1450	16	0.13	0.29	ī	10.0
1470	17	0.11	0.26	Ī	10.0
1490	18	0.10	0.23	$\bar{1}$	10.0
1510	19	0.09	0.20	<u> </u>	10.0
1530	$\overline{20}$	0.08	0.18	ī	10.0
2000	$\overline{21}$	0.07	0.15	ī	10.0
	$\overline{22}$	0.06	0.14	ī	10.0
1 }	$\overline{23}$	0.06	0.13	ī	10.0
	$\mathbf{\tilde{24}}$	0.05	0.12	1 1	10.0
	$\overline{25}$	0.04	0.11	ī	10.0
1580	26	0.04	0.10		10.0
1610	2 7	0.02	0.03	ī	10.0
1630	$\overline{28}$	0.02		ī	10.0
1	281/2			1 1 1	9.0
1650	29			ī	8.0
1	$\frac{1}{29}\frac{1}{2}$			ī	7.0
1670	30			<u> </u>	6.0
1690	31			ī	5.0
17102	322			ĵ i	4.0
1730	33			ī	3.0
1750	3 4			î	2.5
1770	3 5			1 1 1	$\frac{2.0}{2.0}$
1920	40			i	~ . U

¹ These cones are not manufactured, as their estimated softening points lie too close to neighboring cones, and are somewhat irregular.

2 Pure silica behaves like cone 32.

From "The Silicates in Chemistry and Commerce," by W. and D. Asch.

452 METALLURGISTS AND CHEMISTS' HANDBOOK

METALLIC SALTS AS FUSION PYROMETERS¹

Salt	Melting point, deg. C.	Salt	Melting point, deg. C.
Na ₂ SiO ₃	1007	KBr. KI. 5.8KCl + 4.2NaCl. 3NaCl + 7KBr. Ba(NO ₂) ₂ . 5KCl + 5K ₂ CO ₂ . 3Na ₂ CO ₃ + 3K ₂ CO ₃ + 2NaCl- + 2KCl. Ca(NO ₂) ₂ . 3K ₂ SO ₄ + 3Na ₂ SO ₄ + 2NaCl- + 2KCl. NaOH. NaNO ₃	730
K ₂ SO ₄	1070		682
BaCl ₂	955		655
K ₂ SiO ₃	890		625
Na ₂ SO ₄	865		600
5K ₂ SO ₄ + 5Na ₂ SO ₄	850		580
3K ₂ SO ₄ + 7Na ₂ SO ₄	830		560
2K ₂ SO ₄ + 8Na ₂ SO ₄	825		550
Na ₂ CO ₃	810		520
NaCl	800		320
KCl	775		313

¹ HOFMAN, "General Metallurgy."

ERHARD AND SCHERTEL FUSION PYROMETERS1

Composition	Melting point, deg. C.	Composition	Melting point deg. C.
100Ag	961	60Au 40Pt	1320
80Ag 20Au	975	55Au 45Pt	1350
60Ag 40Au	995	50Au 50Pt	1385
40Ag 60Au	1020	45Au 55Pt	1420
20Ag 80Au	1045	40Au 60Pt	1460
100Au	1063	35Au 65Pt	1495
95Au 5Pt	1100	30Au 70Pt	1535
90Au 10Pt	1130	25Au 75Pt	1570
85Au 15Pt	1160	20Au 80Pt	1610
80Au 20Pt	1190	15Au 85Pt	1650
75Au 25Pt	1220	10Au 90Pt	1690
70Au 30Pt	1255	5Au 95Pt	1730
65Au 35Pt	1285	100Pt	17752

¹ Hofman, "General Metallurgy." ² 1755°C. is probably the correct figure.

COLOR SCALES¹

White and Taylo	r	Pouillet	•	Howe	
Name of color	Deg. C.	Name of color	Deg. C.	Name of color	Deg. C.
	566 635 746 843 899 941 996	red	525 700 800 900 1000 1100 1200 	Lowest visible red in dark. Lowest visible red in daylight Dull red Full cherry Light red Full yellow White	850 950 1000 1150

¹ Hofman, "General Metallurgy," p. 138.

Loss of Heat by Radiation

(Loss in Gram-calories per Square Centimeter of Surface at 100°C. to Surrounding Bodies at 0°C.—Peclet's Figures)

Polished brass Copper Polished sheet iron Leaded sheet iron Ordinary sheet iron	0.00068 0.00189 0.00273	Glass	0.01332 0.01410 0.01222
---	-------------------------------	-------	-------------------------------

To correct the above figures for various other ranges of temperature than from 100°C to 0°C., multiply by the factors below.

100°-0° 150°-0° 200°-0° 300°-0° 400°-0° 500°-0°	1.0 2.0 3.3 7.0 12.0 18.3	600°-0° 700°-0° 800°-0° 900°-0° 1000°-0°	26.0 35.0 45.3 57.0 70.0
--	--	--	--------------------------------------

In general, radiation from hot bodies to cold surroundings will vary as the differences of the fourth powers of the absolute temperatures.

Heat Emissivity of Various Surfaces¹

Black body	1.00
Copper, oxidized	0.72
Copper, calorized	0.26
Silver	0.03
Cast iron, bright	0.22
Cast iron, oxidized	0.62
Cast iron, aluminum painted	
Cast iron, gold enamelled	
Monel metal, bright	
Monel metal, oxidized	
Brick surfaces (probably)	0.60-0.75

DIFFUSIVITY²

Aluminum Antimony Cadmium Copper Bismuth Gold Iron Lead Magnesium Mercury Nickel Platinum Silver Cast steel Tin Zinc	0.14 0.47 1.13 0.07 1.18 0.17 0.24 0.88 0.03 0.15 0.24 1.74 0.12	Air Cotton Cork Ebonite Rock material (granite, etc.). Ice Concrete Average damp soil Water Fire brick Building brick Silica Silica brick Magnesia	0.18 0.0009 0.0001 0.0001 0.012 0.011 0.006 0.0049 0.0014 0.0067 0.005 0.003 0.0053-0.0098 0.0126-0.0226
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¹ Boyd Dudley, Jr., "Penn. State Min. Quart.," April, 1915.

² The property of diffusing and transmitting heat is dependent on the conductivity, the density and the specific heat of the body. Thus the coefficient of diffusivity, $D = \frac{K}{WS_1}$ where K is the thermal conductivities in gram-calorie-seconds per cm. per 1°C. F. T. Havard, "Refractories and Furnaces."

CCNDUCTIVITY, DENSITY, POROSITY AND PREMEABILITY OF REFRACTORY MATERIALS!

	Condu	Conductivity	Ã	Density	Domina	Perm	Permeability	é
Material	Gram-cal. per 6q. cm. per hr. per 1°C dif- ference	Kgoulhr. per sq. m. per m. per 1°C. difference	True	Appar- ent 4	in per cent, of volume	Cm. ³ sec. per sq. m. per cm.	Litbr. per eq. m. per m.	perature of burning
Fire-olay brick.	0.0087	1.32	9.61	1.81	30.8	0.0409	14.72	1050
Checker brick.	0.0030	27.	60 K	600	27.00	0.0465	16.74 74 99	1800
Silves brick	0.00	12.	100	125	850 840 840 840 840 840 840 840 840 840 84	0.0082	2000	1050
Magnesia brick		120	8	8	41.0	0.0087	2	1300
Carborundum brick	0.0033	3. 38.	86	35. 1.98	386	0.0053	1.96.1	200
Carborandum brick,	0.0067	25. 25. 25.	24 28 28	3.19 3.19	30. 6 21.3	0.0043	20.55	1300
rrek (c	0.0034	25	85.4 88.4	2 F	26 4	0.0075	24.45	1300
Graphite brick	000	00 -	9	1.78	26.0	0.0	0.0	
Foreeasts Building brick.	0 0037	8.50	8	1.90	25.7	0.0015	0.53	1000
Light clay	0.0024	98.0	٠,	1.41	45.7	0.0164	2.90	:

In general, the conductivity increases with an increase in the original temperature of burning and the temperature of using. In this connection it should be noted that commercial silica brick are burned at higher temperatures than 1300°C, and probably 200° higher than clay brick. The ordinary American saids brick is therefore probably a better conductor than is the American Chromite, however, has a clay brick and for metallurgical furnace work the above figures are probably extremely misleading. conductivity with practically no temperature coefficient. 1 F. T. Havann, "Refractories and Furnaces."

HEAT CONDUCTIVITIES OF REFRACTORIES¹

	Ch.	-	·	sp. gr.		Ter rang meas me	ge of sure-		
Specimen	Che: analy		Thickness	Apparent s	True sp. gr	Lower surface, deg.	Upper surface, deg.	Mean k	Remarks
Fire-clay brick (Farnley).	SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MgO Alk.	0.3	132"	1.95	2.54	825 970 1080 1440 1100 13 5 0	300 330 550 420	0.0029 0.0029 0.0036 0.0040 0.0033 0.0039	Hard fired to Seger cone 10—11 approximately. Another specimen.
Fire-clay brick (Farnley).	As ab	ove	11/2"	1.90	2.67	1005 1020		0.00165 0.00120	· · · - =
Silicious brick (Farnley).	SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO & Tr Alk,	82.5 16.1 1.2 MgO		1.82	2.53	1300	310	0.0025	With many silica grains.
Silica brick (Gregory).	SiO ₂ Al ₂ O ₃ FeO ₃ CaO	95.3 2.0 1.1 1.5	21/2"	1	2.32 2.32	1210	295 370	0.0039 0.0030 0.0035 0.0042	Another specimen. Both coarse grained.
Magnesia brick (Mabor).	SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MgO	0.4		2.40	3.51	380 560 600 700 .750 875 1025 1040 1370	325 400 450 470 525 580 590	0.0170 0.0151 0.0148 0.0132 0.0116 0.0110 0.0101 0.0098 0.0091	Finer grained than the above.

The chemical analysis and porosity data were not derived from measurements on the actual test brick but on similar specimens of the same make. They will correspond approximately with those of the test bricks.

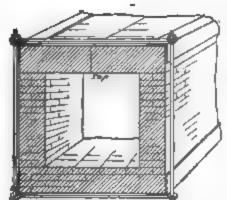
¹ G. Dougill, H. J. Hodsman, and J. W. Cobb in Journ. Soc. Chem. Ind., May 15, 1915.

HEAT CONDUCTIVITIES OF REFRACTORY MATERIALS¹ (See also Table on pp 455 and 456.)

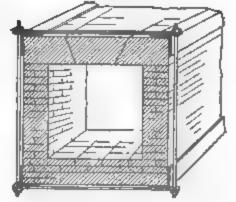
	He	at conductivity	_
Material	Gallons cal. sec. p. sq. cm. p. cm. p. 1°C diff.	Kg. cal. hr. p. sq. m. per m. p. 1°C. diff.	Relative per cent.
Graphite brick Carborundum brick Magnesia brick Chromite brick Chromite brick Checker brick Gas-retort brick Building brick Bauxite brick Glass pot Terra cotta Silica brick Kieselguhr brick	0.025 0.0231 0.0071 0.0057 0.0042 0.0039 0.0038 0.0035 0.0027 0.0023 0.0023 0.0020 0.0018	9.0 8.32 2.54 2.05 1.50 1.42 1.36 1.26 1.19 0.96 0.84 0.71 0.64	100.0 92.4 28.4 22.8 16.7 15.8 15.2 14.0 13.2 12.4 9.3 7.8 7.1

The above are average conductivities only. The conductivity varies with the porosity, permeability, size, character and number of grains and pores in the brick, the temperature at which the brick was burned and the temperature at which it is used. In general the conductivity is greater the higher the temperature at which the brick is burned. Thus, a clay brick burned at 1050°C. has a conductivity of 1.32, while the same brick burned at 1300°C. has a conductivity of 1.81 (HAVARD). The conductivity also increases with increase of temperature of the experiment.

Arch Construction²



Showing way of covering over a flue on a small furnace without use of an arch. This is practical to spans as large as 30° to 36°. This form of construction is particularly applicable where a flat covering is advantageous.



Showing manner of laying a "dutch arch," simple and cheap for spans up to 30" to 40" or even larger. This form of construction is particularly good where flat cover of larger size than the preceding is desired.

HAVARD, "Furnaces and Refractories," p. 280.

Metallurgical and Chemical Engineering, November, 1913.

SECTION IX

MECHANICAL ENGINEERING AND CONSTRUCTION

CAPACITY OF BELT CONVEYORS1

By R. W. Dull

Chief Engineer, Stephens-Adamson Mfg. Co.

The capacity of belt conveyors is a subject upon which various engineers differ materially in results they have published. We suspect that most of the matter published is purely theo-

retical and not based on actual performance.

There are several conditions which influence the capacity rating; the main one, and the one we will first discuss, is the manner of feeding the conveyor. If the conveyor is fed with a feeder, the maximum capacity is possible, but if the feed is intermittent, the capacity will, of course, be proportionately less. It is usually an advantage to put in a feeding device of some kind if the feed is irregular, as it is often possible to cut down the size of the conveyor, which difference in cost will more than pay for the cost of the feeding device, as well as cut down the size of the driving connections. Uniform loading of the belt also makes the operation of the conveyor less trouble-some and usually is desirable in the different processes throughout a plant.

I have made a chart, which is based on good feeding conditions, as we must have some basis from which to start. This chart has curves for various kinds of material, based on the belt speed which I recommend that they should run for the particular kind of material. This speed is given in the curves. If good feeding conditions are not obtainable, allowance must be made on the chart. This is a condition which varies so much we cannot set down any rigid rule, but must leave it to the judgment of the user of the chart to make proper allowance. Variation as great as 50 per cent. is likely and certainly many

where 75 per cent. of chart rating is advisable.

Materials undoubtedly will be handled which are not given in the chart, but as a similar substance can be selected, the chart can still be used.

The speed of the belts carrying various substances has been studied carefully to suit all conditions, as for instance, lump coal and coke, if carried too fast, will be broken up too much

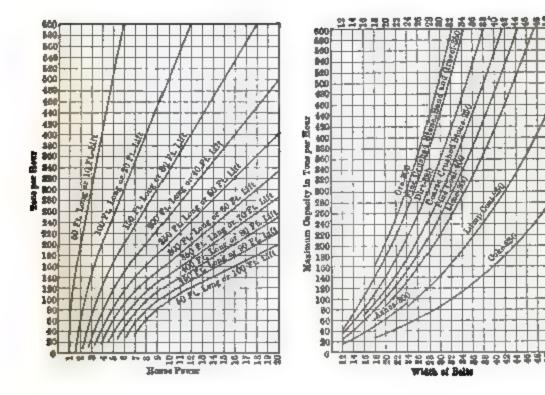
¹ "The Chemical Engineer," Vol. X, No. 2.

to suit the market; and again, very fine material, if carried too fast, will make the mill too dusty.

Some of the curves are stopped off at a certain size belt, as with large pieces, it is not advisable to use a conveyor any nar-

rower, regardless of what capacity is required.

Material with large lumps, on an inclined conveyor, will be apt to roll back some, so the capacity allowance should be liberal, and the speed should be reduced slightly, if the conveyor is carrying material down an incline, as the motion of the belt will start the lumps rolling down. These lumps may possibly jump out of the trough of the belt.



Conveyors going up an incline and fed uniformly, can usually go up an angle whose tangent is greater than the coefficient of friction of material on the belt, because the material forms a back stop all the way up the incline. But if the feed is intermittent, the material is apt to get started down the incline and the motion of the belt will have no influence on the motion of the material.

Conveyors should be fed so that the material is delivered in the direction of motion of the belt and with the same velocity as the belt is moving, if possible. The writer has devised a spout to accomplish this purpose and adjustment is possible to suit various kinds of material and different belt speeds. The spout is also made with a bar screen bottom which lets the fine material through onto the belt first which makes a cushion on which the larger lumps fall and saves a great deal of wear on the belt. It is not advisable to make small conveyors, such as 12-in. belts, too long, for the material will shift some and lose off before it reaches the end of the conveyor, and liberal allowance in capacity should be made if such a conveyor is installed.

The problem of belt conveyor capacity should be studied carefully and the allowances should be liberal. There have been very many disappointments in results caused by a too hasty decision or too great a desire to keep the first cost down.

Most firms are willing to help the purchaser, and it is usually a good plan to take up the matter of capacity with the manufacturer. It is not always easy for the manufacturer to find out all the conditions within so short an interval of time as he usually has at his disposal, and unless the manufacturer has had considerable experience with this type of conveyor, the purchaser may be led to install apparatus which gives him very disappointing results.

CAPACITY OF BELT CONVEYORS IN TONS OF COAL PER HOUR¹

Width of			Velocity	of belt, fe	et per mir	nute	·
belt, inches	300	350	400	450	500	550	600
12	27.0	31.5	36	40.5	45.0	49.5	54.0
14	36.7	42.8	49	55.2	61.3	67.4	73.6
16	48.0	56.0	64	72.0	80.0	88.0	96.0
18	60.7	70.8	81	91.2	101.0	111.0	135.0
20	75.0	87.5	100	112.5	125.0	137.5	150.0
24	108.0	126.0	144	162.0	180.0	198.0	216.0
· 30	168.7	197.0	225	253.0	281.0	307.0	338.0
36	243.0	283.0	324	365.0	405.0	446.0	386.0

For materials other than coal, the figures in the above table should be multiplied by the following coefficients.

Material	Coefficient.	Material	Coefficient
Ashes dampCementClayCoke	1.26	EarthSandCrushed stone	1.4 1.8 2.0

¹ KENT'S "Mechanical Engineers' Pocketbook."

THE NEW AMERICAN STANDARD FOR FLANGES AND FLANGED

	<u>z</u> [2,1	STAN	7 3	A.	E			G
	tees and	nter to , ella, tees, crosses	B-Center to face, long rad- ius elle	ter to	to face	E-Center to face laterals	F-Center to face laterals	e to face	ster of	posts of	Minimum metal thickness of body
- 88 - 88 - 88	AA-Face face, te crosses	A-Center face, elli and croe	B-Center face, lo	C-Center face 45°	D-Face laterals	은 6	25	G-Face to reducers	Diameter flanges	Thicknes flanges	Minimum thickness body
1 114 115 2 2 2)5	7 71/2 8 9	315 334 4 415 5	5 534 6 414 7	134 2 234 234	714 8 9 1014 12	534 6)4 7 8 934	134 134 2 215 215		4 452 8 6 7	13/16 3/16 3/16 3/16	Ne Ne Ne
# # # # # # # # # # # # # # # # # # #	11 12 13 14 14	514 6 614 M	794 834 9 944 104	3 836 4 4 436	18 1436 15 1536 27	10 1156 12 1256 1356	3 3 3 3/2	6 6 7 7 734	734 834 9 934 10	36 136 156 156 156 156	*****
6 7 8 9 10	16 17 18 20 21	8 81/2 9 10 11	1114 1294 14 1514 1614	5 534 534 6	18 2014 22 24 2514	1414 1614 1714 1914 2014	2)4 4 4)4 4)4 5	9 10 11 11/4 12	11 12}4 13}4 15 16	1 11/6 11/6 11/6 13/4	9/16 9/4 13/14 9/4
12 14 15 16 18	24 28 29 30 83	12 14 14)4 15 16)4	19 2154 2234 24 2534	716 716 8 8 816	30 33 34)4 30)4 39	24½ 27 50 30 32	514 6 6 614 7	14 16 17 18 19	19 21 2214 2334 25	114 136 136 176 176	19/0 1/4 1/4 1/4
20 22 24 26 28	36 40 44 46 48	18 20 22 22 24	20 31½ 34 36¼ 30	936 10 11 13 14	43 46 49)4 53 56	85 8714 4015 44 4616	8 81/4 9 9 91/4	20 22 24 26 28	2714 2914 32 3414 3614	113/6 113/6 13/6 2 2/14	116 116 116 116 116 116
30 32 34 36 38	50 52 54 56 58	25 26 27 28 29	4134 44 4634 49 5134	15 16 17 18 19	50	40	10	30 32 34 36	3834 4134 4334 48 4834	256 254 256 256 256	17/4 13/2 19/4 15/4 11/0
40 42 44 46 48	60 62 64 66 68	30 31 32 33 34	54 5014 59 6114 64	20 21 22 23 24				40 42 44 46 48	5034 53 5514 5714 5912	214 254 246 2114 234	134 1134 136 1151 2
50 53 54 56	70 74 78 82 84	35 37 39 41 42	6634 69 7134 74 7634	25 26 27 28 29				50 52 54 56 58	6134 64 6634 6834 71	234 234 3 3 3 3	23/16 23/16 23/16 23/16 23/16

THE NEW AMERICAN STANDARD FOR FLANGES AND FLANGED FITTINGS. Continued

					STAN	DARD					
Size	AA-Face to face, teem and crosses	A-Center to face, ella, tees and crosses	B-Center to face, long rad- ius ells	C-Center to face 45° ells	D-Face to face laterals	E-Center to face laterals	F-Center to face laterals	G-Face to face reducers	Diameter of	Thickness of flanges	Minimum metal thick- ness of body
60 62 64	88 90 94	44 45 47	79 8134 84	30 31 32				60 62 64	73 75% 78	316 316 316	27/14 21/4 29/14
66 68 70 72 74	96 100 102 106 108	48 50 51 58 54	8634 89 9134 94 9634	33 34 35 36 37				66 68 70 72 74	80 8214 8414 8614 8814	396 396 316 316 356	256 211/a 236 213/a 213/a 276
76 78 80 82 84	112 116 118 120 124	56 58 59 60 62	99 10134 104 10634 109	38 39 40 41 42				76 78 80 81	92 9554 9734 9834	346 346 346 376 376	215/6 8 31/6 31/6 33/6
88 90 92 94	126 130 134 136 138	68 65 67 68 69	11134 114 11634 119 12134	43 44 45 46				66 88 90 92	103 10434 10634 10834 111	4 4 4)6 4)6 4)6	334 256 236 236 236 256
98 98 100	142 148 148	71 73 74	124 12614 129	48 49 50				96 98 100	11834 11634 11734	4)4 4)4 4)4	356 3136 334

THE NEW AMERICAN STANDARD FOR FLANGES AND FLANGED FITTINGS. Continued

				型		To the second			
				Stani	ARD		<u> </u>		
Sise	*Size of outlet and smaller	AA-Face to face, run	A-Center to face, run	B-Center to face, out-	Sise	Size of outlet and smaller	AA-Face to face, run	A-Center to face, run	B-Center to face, outlet
1 114 114 2 214					42 44 46 48 50	28 28 30 32 32	46 46 48 52 52	23 23 24 26 26	30 31 33 34 35
3 3½ 4 4½ 5	to 9 same sions	in. incl	ng fitting lusive he to face ght size f	ave the dimen-	52 54 56 58 60	34 36 36 38 40	54 58 58 62 66	27 29 29 31 33	36 37 39 40 41
6 7 8 9 10	6	18	9	934	62 64 66 68 70	40 42 44 44 46	66 68 70 70 74	33 34 35 35 37	42 44 45 46 47
12 14 15 16 18	8 9 9 10 12	20 22 23 24 26	10 11 1132 12 13	11 13 13½ 14 15½	72 74 76 78 80	48 48 50 52 52	80 80 84 86 86	40 40 42 43 43	48 49 50 52 53
20 22 24 26 28	14 15 16 18 18	28 28 30 32 32	14 14 15 16 16	17 18 19 20 21	82 84 86 88 90	54 56 56 58 60	88 94 94 96 100	44 47 47 48 50	54 56 57 58 61
30 32 34 36 38	20 20 22 24 24	36 36 38 40 40	18 18 19 20 20	23 24 25 26 28	92 94 96 98 100	60 62 64 64 66	100 104 106 106 110	50 52 53 53 55	62 63 64 65 67
40	26	44	22	29			• • • • • • • •	 	

THE NEW AMERICAN STANDARD FOR FLANGES AND FLANGED FITTINGS. Continued

				Extra	HEAV	V Y			
Sise	* Size of outlet and smaller	AA-Face to face, run	A-Center to face, run	B-Center to face, out-	Sise	* Size of outlet and smaller	AA-Face to face, run	A-Center to face, run	B-Center to face, out-
1 114 114 2 214 3 314 4 414 5	in. to	o 9 in. ame ce ions a	cing fit inclusiventer to s straig	re have	16 18 20 22 24 26 28 30 32 34	10 12 14 15 16 18 18 20 20 22	25 28 31 33 34 38 41 41 44	1234 14 1534 1634 17 19 19 2034 2034 22	15½ 17 18½ 20 21½ 23 24 25½ 26½ 28
6 7 8 9 10 12 14 15	6 8 9	18 21 23 23	9 10½ 11½ 11½	11 12½ 14 15	36 38 40 42 44 46 48	24 24 26 28 28 28 30	47 47 50 53 53 55 58	23½ 23½ 25 26½ 26½ 26½ 27½ 27	2914 3014 3114 3314 3414 3514 3714

THE NEW AMERICAN STANDARD FOR FLANGES AND FLANGED FITTINGS. Continued

	₹~	14.AM	7		- - -	-A-	7	A		E	
	17		身:		4 -	(Φ)	了一	K	J D		E
	4. £.	, _	LĪ.	<u></u>	II. Extra	HEAVY	Ĭ.		TE A		5
		20				LIEAVI					
	AA-Face to face, tees and crosses	A-Center to face, ells, tees and crosses	B-Center to face, long ra- dius ells	C-Center to face 45° ella	D-Face to face, laterals	E-Center to face, laterals	F-Center to face, laterals	G-Face to face, reducers	Diameter of flanges	Thickness of flanges	Minimum metal thick- ness of body
Sise	₹#8	A g	P 22.9	<u>ي.</u> ل	Ų.	F. E.	F-(မှ နို	Ü	T. d.	M a a
1 134 134 2 2 234	8 834 9 10 11	4 4)4 4)4 5 5	5 51/2 6 61/2 7	2 21/4 23/4 8 31/2	8½ 9½ 11 11½ 13	614 714 814 9 1014	2 234 234 234 234		41/2 5 6 61/2 71/2	13/16 34 13/16 7/8	}2 }4 }4 }4 }4 910
3 3 4 4 4 5	12 13 14 15 16	6 61/2 7 71/2 8	734 812 9 912 1014	314 4 414 414 5	14 15½ 16½ 18 18½	11 1254 1354 1452 15	3 3 3 3 3 3 3	6 614 7 714 8	814 9 10 1014 11	11/6 13/6 11/4 15/6 13/6	916 916 58 58 1116
6 7 8 9 10	17 18 20 21 23	814 9 10 1014 1114	111/2 123/4 14 15/4 16/2	512 6 6 612 7	21½ 23½ 25½ 25½ 27½ 29½	173/2 19 203/2 223/2 24	4 412 5 5 5 5 512	9 10 11 111/2 12	-1234 14 15 1634 1735	17/6 11/2 15/6 13/4 17/6	34 13/6 13/6 7/8 15/16
12 14 15 16 18	26 30 31 33 36	13 15 15½ 16½ 18	19 2134 2234 24 2632	8 834 9 934 10	3334 3734 3934 42 4534	2734 31 33 3434 3734	6 6)4 6)4 7)4 8	14 16 17 18 19	201/2 23 241/2 251/2 28	2 216 236 214 236	1 11/6 13/16 11/4 13/6
20 22 24 26 28	39 41 45 48 52	19½ 20½ 22½ 22½ 24 26	29 311/2 34 361/2 39	10½ 11 12 13 14	49 53 · 571⁄2	4014 4314 4714	814 914 10	20 22 24 26 28	30½ 33 36 38¼ 40¾	2½ 258 234 213/16 215/16	11/2 19/16 15/8 11/3/16 17/8
30 32 34 36 38	55 58 61 65 68	271/2 29 301/2 321/2 34	41½ 44 46½ 49 51½	15 16 17 18 19				30 32 34 36 38	43 45¼ 47½ 50 52¼	3 31/8 31/4 33/8 37/16	2 21/8 21/4 23/8 27/16
40 42 44 46 48	71 74 78 81 84	3514 37 39 4014 42	54 56}2 59 61}2 64	20 21 22 23 24				40 42 44 46 48	54½ 57 59¼ 61½ 65	39/16 311/16 33/4 37/6 4	29/16 211/16 213/16 27/8 3

THE NEW AMERICAN STANDARD FOR FLANGES AND FLANGED FITTINGS. Continued

	C	D					C	HEAV	×		
***************************************			ARD						HEAV	Y	
Sise	*Size of branch and smaller	C-Face to face, run	D-Center to face, run	E-Center to face, run	F-Center to face, branch	Size	*Size of branch and smaller	C-Face to face, run	D-Center to face, run	E-Center to face, run	F-Center to face, branch
1 114 115 2 215	in. ir	iclusiv to fac	ing fit e have e dim e fittin	e same ension	cen-	1 1¼ 1¼ 2 2½ 3	l in ir	relusiv	e have	tings is same ension	cen-
3 3 4 4 4 5	214 214 3	13 13 14	11 11 12	2 2 2	11 11 12	3 314 4 414 5	21/2 21/2 3	14 15 16	12 12½ 13½	2 2)4 2)4	13 13½ 14½
6 7 8 9 10	3 312 4 412 5	15 16 16 17 18	1334 1434 1434 1534 17	11/2 11/2 11/2 11/2 11/2	13½ 15 15½ 16½ 16½	6 7 8 9 10	3 314 4 414 5	17 18 20 21 23	14\\\delta\) 15\\\delta\) 17\\\delta\) 18\\\delta\) 20\\\delta\)	214 214 214 214 214 214	15½ 16½ 18½ 18½ 19½ 21½
12 14 15 16 18	6 7 7 8 9	20 22 23 24 26	19 21 22 23 25	1 1 1 1	20½ 23 24 25½ 27½	12 14 15 16 18	6 7 7 8 9	26 29 30 32 34	2314 2614 2714 29 31	214 214 214 3 3	241/4 271/4 281/4 -301/4 321/4
20 22 24 26 28	10 10 12 12 14	28 29 32 35 37	27 2814 3114 35 37	1 14 14 0 0	2914 3114 3414 38 40	20 22 24	10 10 12	37 40 44	34 37 41	3 3 3	36 39 43
30	15	39	39	0	42						

MECHANICAL ENGINEERING

SAFE LOADS FOR ROPES AND CHAINS

(In pounds)

Prepared by National Founders' Association

CAUTION: When handling molten metal, wire ropes and chains should be 25 per cent. stronger than indicated in table.

NOTE.—The eafe lo	ada i:	n table	When used straight	When used at 60° angle	When used at 45° angle	When usi at 80° angle
are for each single ro When used double multiples the loads oreased proportionate	pe or or in may	chain.			\triangle	
		Dia.				
Prow Street Wine I (6 strands of 19 or wires.) If crucible rope is used reduce I one-fifth.	steel	36" 36 36 36 36 116 116 116	1,500 2,400 4,000 6,000 8,000 10,000 13,000 16,000 19,000 22,000	1,275 2,050 3,400 5,100 6,800 8,500 11,000 13,500 16,000 19,000	1,050 1,700 2,800 4,200 5,600 7,000 9,000 11,000 13,000 16,000	750 1,200 2,000 3,000 4,000 5,000 6,500 8,000 9,500 11,000
Chane Chain (Best grade of wroniron, hand-made, tes	ught ted,	Din. of iron 14" 146 141 116 116 116 116	600 1,200 2,400 4,000 5,500 7,500 9,500 12,000 15,000 22,000	500 1,025 2,050 3,400 4,700 6,400 8,000 10,200 12,750 19,000	425 850 1,700 2,800 3,900 5,200 6,600 8,400 10,500 16,000	350 600 1,200 2,000 2,750 3,700 4,700 6,000 7,500
MANILA ROPS (Best long fiber grade.)	Dia. 36" 36 34 134 134 134 134 134 134 134 134 134	Cir. 1 " 1142 2 14 2 14 3 14 3 14 3 14 4 14 5 14 6 7 14 9	120 250 360 520 620 750 1,000 1,200 1,800 2,100 2,800 4,000 6,000	100 210 300 440 520 625 850 1,025 1,350 1,800 2,400 3,400 5,100	85 178 250 260 420 525 700 850 1,100 1,500 2,000 2,800 4,200	50 125 180 260 375 500 600 800 1,000 2,000 3,000

ANNEALING CHAINS1

For many years The Travelers Insurance Company has recommended the periodical annealing of chains that are subject to severe usage, such as those that are used on cranes, dredges, and chain hoists, and for slings and for other heavy work, although many prominent authorities firmly believe that such treatment is inadvisable. A recent canvass of a considerable number of chain manufacturers shows that those in favor of the annealing process outnumber those opposed to it by about five to one, although the advocates of annealing are not in harmony as to the methods employed, the frequency of annealing, the temperature to which the chains are to be subjected, or

the length of time required to insure good results.

All chain manufacturers, and practically all chain users, are aware of the fact that rough usage, shocks, and twists tend to weaken chains. A change gradually occurs in the molecular composition of the material, and the strength of the chain becomes seriously impaired. This is known as "fatigue" of There may be no visible evidence of this deteriorathe metal. tion, although a careful microscopic examination would doubtless disclose a multitude of small cracks; but a person accustomed to the use of chains knows that deterioration is going on, and that eventually the chains will fail. When a chain has been in service for a sufficient length of time to make it unsafe for use at the load for which it was originally designed, it would be desirable to discard it, or at least to use it only for lighter loads: but such a course is not always practicable, nor, according to the views of the advocates of annealing, is it necessary, because the process of annealing counteracts the effects of fatigue and restores the chain to nearly its original strength.

As to the proper method of doing the work, a pyrometer-controlled muffle furnace is the best thing possible. Open fires are bad because it is difficult to guess the temperature of the chain, and impossible to hold the temperature steady. The Committee on Heat Treatment, of the American Society for Testing Materials, recommends the following annealing tem-

peratures.

Carbon content	Anneali	ng temperature
Less than 0.12 per cent	875–925°C.	(1607–1697°F.)
0.12-0.25 per cent		
0.30-0.49 per cent		
0.50-1.00 per cent		

If an open fire must be used, heat to a cherry red in a wood fire, then let the fire die out, and allow the chain to cool in the ashes.

Various methods for testing chains are employed by persons who have no faith in the annealing process. The method advocated by the Yale & Towne Manufacturing Co. and by the Brown & Sharpe Manufacturing Co. is to make use of a gage 3

¹ From the "Travelers Standard," p. 122, 1915.

ft. long. Every new chain is marked with a prick-punch at intervals of 3 ft., and at each subsequent inspection of the chain the prick-punch marks are compared with the gage. If it is found that a section of the chain between two of the marks has stretched by an amount equal to one-third of the length of a link, the chain is considered unsafe and is condemned, or is used in some place where it will be subjected only to light loads. It is sometimes found that only a single section of the chain must be discarded. The experience of users of chains who have adopted this method for testing them has been satisfactory, in the main, and accidents from breaking chains have been materially reduced by it. Manifestly, however, it would not apply without modification to chains having unusually large links.

Many authorities on chains, even though admitting that sling chains should be annealed, insist that block chains that pass over sheaves should not be treated in this way. The danger from molecular changes caused by overloading the chains may be greatly diminished by proper annealing, but when distortion of the links occurs in block chains the chains no longer fit the sheaves, and excessive wear results, often accompanied by severe and badly distributed stresses. No amount of annealing can restore the links to their original lengths, and the only practical remedy, when such distortion has occurred, is to substitute new chains.

FIBER ROPE KNOTS AND HITCHES—AND HOW TO MAKE THEM

The principle of a knot is that no 2 parts which would move in the same direction if the rope were to slip, should lie alongside of and touching each other. This principle is clearly shown in

the square knot (I).

A great number of knots have been devised, of which a few of the most useful are herewith illustrated by courtesy of C. W. Hunt Company, of New York. In the engravings they are shown open, or before being drawn taut, in order to show the position of the parts. The names usually given to them are:

A. Bight of a rope.

B. Simple or overhand knot.

C. Figure 8 knot. D. Double knot.

E. Boat knot.

F. Bowline, first step.

G. Bowline, second step.

H. Bowline, completed.1. Square or reef knot.

J. Sheet bend or weaver's knot.

K. Sheet bend with a toggle.

L. Carrick bend.

M. "Stevedore" knot completed.
N. "Stevedore" knot commenced.

O. Slip knot.

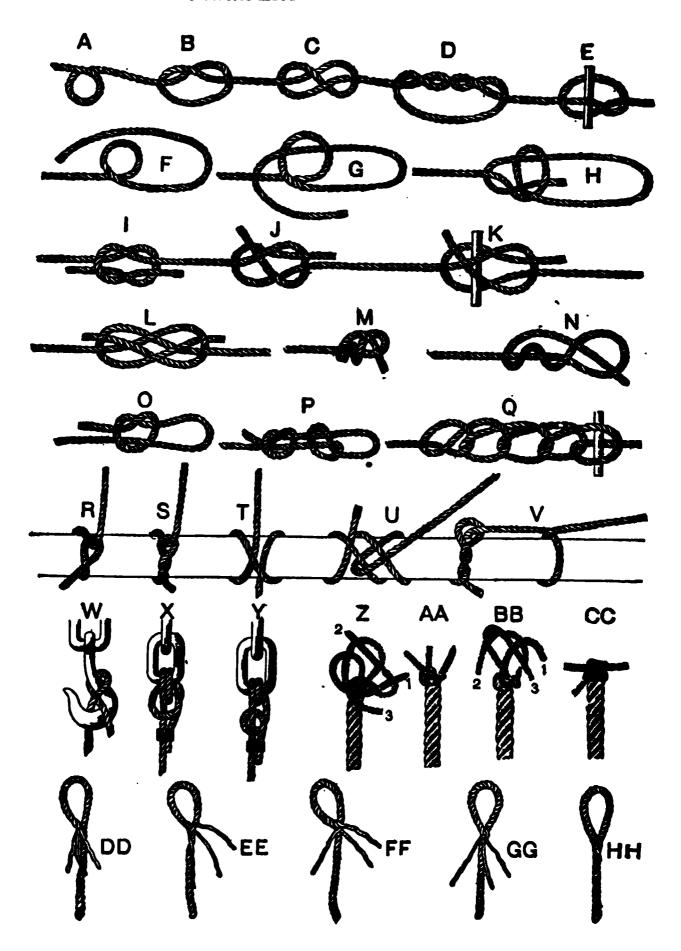
P. Flemish loop.

Q. Chain knot with toggle. R. Half-hitch.

S. Timber-hitch.

T. Clove-hitch.

U. Rolling-hitch.
V. Timber-hitch and half-hitch.
W. Blackwall-hitch.



X. Fisherman's bend.

Y. Round turn and half-hitch.

Z. Wall knot commenced.

AA. Wall knot completed.

BB. Wall knot crown commenced.

CC. Wall knot crown completed.

DD to HH. Eye splice commenced and completed.

The bowline (G) is one of the most useful knots; it will not slip, and after being strained is easily untied. It should be tied with facility by everyone who handles rope. Commence by making a bight in the rope, then put the end through the bight and under the standing part, as shown in the engraving, then pass the end again through the bight, and haul tight.

The square or reef knot (1) must not be mistaken for the "granny" knot that slips under a strain. Knots (H, K and M) are easily untied after being under strain. The knot (M) is useful when the rope passes through an eye and is held by the knot, as it will not slip, and is easily untied after being strained.

The wall knot looks complicated, but is easily made by pro-

ceeding as follows:

Form a bight with strand 1, and pass the strand 2 around the end of it, and the strand 3 around the end of 2, and then through the bight of 1, as shown in engraving Z. Haul the ends taut, when the appearance is as shown in the engraving AA. The end of the strand 1 is now laid over the center of the knot, strand 2 laid over 1, and 3 over 2, when the end of 3 is passed through the bight of 1, as shown in the engraving BB. Haul all the strands taut, as shown in the engraving CC.

The "stevedore" knot (M), (N) is used to hold the end of a rope from passing through a hole. When the rope is strained

the knot draws up tight, but it can be easily untied when the

strain is removed.

If a knot or hitch of any kind is tied in a rope, its failure under stress is sure to occur at that place. Each fiber in the straight part of the rope takes proper share of the load, but in all knots the rope is cramped or has a short bend, which throws an overload on those fibers that are on the outside of the bend and one fiber after another breaks until the rope is torn apart. The shorter the bend in the standing rope, the weaker is the knot.

The curvature of wire ropes over pulleys should be such that the bending stress plus the load stress will not produce a tension in the wires greater than the elastic limit.

The bending stress in lb. =
$$\frac{Ea}{2.06\frac{R}{d} + c}$$

where E = the modulus of elasticity; R = radius of bend in inches; d = diameter of the individual wires in inches; and C = a constant depending on the number of wires in the strands (for 7-wire rope C = 9.27; for 12-wire, 12.36; for 15-wire, 15.45).

The tension of a rope is measured by its sag at the center of the arc. Let h = deflection in ft.; w = wt. of rope in lb. per running foot; t = tension;

l = chord of arc in ft.; then $h = \frac{wl^2}{8t}$.

FORMULAS FOR PUMPS AND PIPING1

To find	Given	Formulas
 Pressure in lb. per sq. in. = P. Head in ft. = H. Horsepower required to raise water (theoretical). Volume of water discharged by pipe (neglecting bends and friction). Theoretical capacity of single-acting pump. Dia. in in. of single-acting pump 	Head in ft. = H Pressure in lb. per sq. in. = P. Gal. per min. = G. Head in ft. = H. Internal dia. of pipe in in. = D. Head in ft. = H. Length of pipe in yards = L. Area of ram in in. = A. Stroke in in. = S. No. of strokes per min. = N. Gal. per stroke = G.	H.p. = $\frac{G \times H}{3,300}$ Gal. per min.: = $28\sqrt{\frac{D^5 \times H}{L}}$ Gal. per min.: = $\frac{A \times S \times N \times 6.25}{1728}$
to deliver given number of gals. per stroke. 7. Feet head lost by friction in pipes = F.	Stroke in ft. = S. Gal. per min. = G. Length of pipe in yards = L. Internal dia. of pipe in in. = D.	Dia. of pump = $\sqrt{\frac{31G}{S}}$ (allowing 5 per cent. waste). $F = \frac{G^2 \times L}{(3D)^5}$
 8. Approx. weight of water in vertical pipes in lb. = W. 9. Thickness of castiron pipes in in. = T. 	Internal dia. of pipe in in. = D. Length of pipe in yards = L. Internal dia. of pipe in in. = D. Pressure in lb. per sq. in. = P.	
10. Delivery per stroke of single-act- ing pump.	Dia. of plunger in in. = D. Stroke in ft. = S.	Gal. delivered per stroke = $\frac{D^2 \times S}{31}$ (allowing 5 per cent. waste).
11. Speed of water through pipes in ft. per sec.	Area in pipe in in. = A. Discharge in cu. ft. per min. = F.P.M. H = head	Velocity ft. per sec. = $\frac{\text{F.P.M.} \times 2.4}{A}$
12. Velocity in ft. per sec. due to head = V. 13. Head from ve-	g = 32.2.	$V = \sqrt{2gH}$ $H = \frac{V^2}{T}$
locity. 14. Imperial gallons 15. Cubic feet	Cubic feet $= C$ Gallons (Imperial) $= G$.	Imperial gallons = $C \times 6.25$. Cubic feet = $G \times 0.16$.

¹ G. S. Burrows, in American Machinist, Aug. 20, 1914.

WATER PRESSURE AT VARIOUS HEADS	WATER	PRESSURE	AT	VARIOUS	HEADS
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Feet head	Pounds per sq. in.	Feet head	Pounds per sq. in.	Feet head	Pounds per sq. in.	Feet head	Pounds per sq. in.	Feet head	Pounds per sq. in.
	• • • • • • •	130 135	56.31 58.48	195 200 205	84.47 86.63 88.80	260 265 270	112.62 114.79 116.96	360	151.61 155.94
• • • • •		140 145 150	60.64 62.81 64.97	210 210 215	90.96 93.14	275 280	110.90 119.12 121.29	380	160.27 164.61 168.94
• • • • •		155 160	67.14 69.31	220 225	95.30 97.49	285 290	123.45 125.62	450	173.27 194.92 216.58
100	43.31	165	71.47	230	99.63	295	127.78	550 600	238.24 259.90
105	45.48	170	73.64	235	101.79	300	129.95	650 700 750	281.56 303.22 324.88
110	47.64	175	75.80	240	103.96	310	134.28		346.54 368.20
115	49.81	180	77.97	245	106.13	320	138.62	950	389.86 411.52
120 125	51.98 54.15	185 190	80.14 82.30	250 255	108.29 110.46	330 340	142.95 147.28		433.18

For heads under 100 ft., take the figure corresponding to 10 (or 100) times the given head and move the decimal point one (or two) places to the left.

Flow of Gas in Pipes¹

If d = Diameter of pipe in inches.

Q = Quantity of gas in cu. ft. per hour. l = Length of pipe in yards.

h = Pressure in inches of water.

s = Specific gravity of gas, air being 1,

then

$$d = \sqrt[5]{\frac{Q^2 s l}{(1350)^2 h}}$$

$$h = \frac{Q^2 s l}{(1350)^2 d^5}$$

$$Q = 1350 d^2 \sqrt{\frac{dh}{s l}} = 1350 \sqrt{\frac{d^5 h}{s l}}$$
or Molesworth gives $Q = 1000 \sqrt{\frac{d^5 h}{s l}}$
while J. P. Gill gives $Q = 1291 \sqrt{\frac{d^5 h}{s (l+d)}}$

1 Kent, "Mechanical Engineers' Pocket Book."

Table for Converting "Compressed Air" into "Free Air" 1

1			48 61 79	28	40 72 05 36 76	14 52 88
		110	$\infty \infty \infty$	• •	00000	
			400	4	<u> </u>	68 05 11 40
		105	H34	∵	0.0000	0.6 1.4
			∞ ∞ ∞ ·		00000	<u> </u>
•		100	82.83	5. E.	.63 .93 .22 .51	27.20
		Ä	LL ®	x x	တတ္တက္က	999
		10	46 57 72	857 887 887	22 23 28 28 28 28 28	569
4		95	7.7.7.1		ထထထတ်တ	10.
777			12 23 37	31.	87 140 40 66 98	911
224		06	7.77	• _	× × × × × ×	000
		2	78 88 02	10 24	440 440 23 440 440	83 13 41
'	1	85	6.7.	• •	~~~ ∞ ∞	ထတ္တ
2	pressure	80	44 53 66	75 88	10 28 10 10	37 67 92
111	pre	00	66.6		×××××	$\infty \infty \infty$
2	age	75	19	51	.05 .05 .05	.91 .19 .42
4777	Ü		52.00		47001 00777	000 000
		20	7.89.00		2020	47.6
OME INDICATE AND			200		73556	37.7
3		65	4. 70.00	9.1	<u>o</u>	6.2.4
		ļ	8004 7070	ПП	<u> </u>	844 677
5		90	5.0	• •	66 57 57 60 10 57	6.5
,			74 80 89		88238	07 26 44
177		55	444	• •	01000000000000000000000000000000000000	66.9
CONTENTING		0	40 46 54		8 11 12 43 43	61 78 95
3		20	यं यं यं	4 4	44555	10 10 10
5		45	06 111 18	30	43 57 70 83 99	14 31 45
		4	सं सं सं	44	चं चं चं चं चं	மமம
r On	7	9	10.07	~ ~	0 1225	2000
	Atmoe	pherio pressure	.45 .12		1.61.6	
	At	pre	444	2 2 2 3		0101
-		er er		·		
		met	9659	322	75 75 78 86 97	989
		Barometer	30. 29.		223.45. 23.45. 23.45.	222
	-	র্	862	70		CICICI
		6 0				<u> </u>
	'	Altitude	0 500 ,000		3,000 4,000 5,000 7,000	8,000 9,000 10,000
		Alta 	7,00,	1,500 2,000	64.00.	% 0,0 0,0
	•	7				

Opposite 4000 and Example: Given 348 cu. ft. of air compressed to 95 lb. pressure at 4000 ft. altitude. below 95 appears the figure 8.53. 8.53 \times 348 = 2968.44 = volume in "free air."

¹ Sullivan Machinery Co.'s Catalog.

HORSEPOWER (THEORETICAL) REQUIRED TO COMPRESS 100 Cu. Ft. Free Air to Various Pressures¹

Gage	Single-stage	Two-stage		vo-stage over compression
pressure			Horsepower	Per cent.
5	1.97			
10	3.61			
15	5.02			
20	6.28			
25	7.44			
30	8.45			
35	9.41			/
40	10.30		• • • • • • • • • • • • • • • • • • • •	
45	11.13			
50	11.92	10.65	1.28	10.70
55	12.67	11.25	1.42	11.22
60	13.37	11.81	1.57	11.72
65	14.05	12.34	1.71	12.18
70	14.70	12.84	1.85	12.61
75	15.32	13.32	2.00	13.04
80	15.91	13.77	2.13	13.40
85	16.48	14.21	2.27	13.77
90	17.04	14.63	2.41	14.12
. 95	17.57	15.03	2.54	14.45
100	18.09	15.42	2.67	14.77
110	19.08	16.15	2.93	15.36
120	20.01	16 . 83	3.18	15.90
130	20.90	17.46	3.43	16.42
140	21.74	18.07	3.67	16.89
150	22.55	18.64	3.91	17.33
160	23.32	19.26 10.78	4.06	17.40
170	24.06	19.78 20.27	4.29	17.80
180	24.77	20.27	4.51 4.70	18.18
190 200	25.46 26.12	$20.74 \\ 21.19$	4.93	18.46 18.88
2 10	20.12	21.54	7.80	
220		21.96		
230		21.30 22.37		
240		$\begin{array}{c} 22.31 \\ 22.76 \end{array}$		• • • • • • • •
250		23.03		
260		23.28		
270		23.84		
280		24.19		
290		24.53		
300		24.85		
350		26.35		
400		27.65		
450		28.85		
500		29.97		• • • • • • • • •
	Abo potenti borro		1 42 22 22 22 2	

To secure the actual horsepower required to compress a given volume of air to any desired pressure, 10 to 15 per cent. should be added to the figures shown above, depending upon the size and type of the compressor, to allow for mechanical losses.

Sullivan Machinery Co.'s Catalog.

APPROXIMATE CUBIC FEET OF FREE AIR AND WORKING PRES-SURE REQUIRED TO RAISE 1 GAL. OF WATER BY AIR LIFT¹

$$V = \frac{L}{H + 34 \times 292.5}$$

$$H = \text{Submergence in feet.}$$

$$L = \text{Lift in feet.}$$

Ft. lb. working power = submergence \times 0.4465 + 7 lb. V = Volume of free air per gallon in cubic feet.

RATIO OF SUBMERGENCE TO LIFT

7.4.	25]	per ce 14-1	ent.		per c }2-1	ent.	43 ₁	per c 34-1		5C 1	per c 1–1	ent.	
Lift in feet	Free air, cu. ft.	Working pressure	Horse- power	F. A. C. F.	W. P.	H. P.	F. A. C. F.	W. P.	H. P.	F. A. C. F.	W. P.	Н. Р.	
20 30 40 50 60 80 100							0.68	40	.070	0.34 0.38 0.41 0.44 0.52 0.58	25 29 34 43	.018 .024 .031 .036 .043 .056	1-Stage
120 140 160. 180 200 250 350 400	1.44 1.57 1.69 1.82 1.96	37 44 52 59	.172 .207 .241	1.15 1.27 1.40 1.50	52 63 74 85 96	.154	1.31	61 67 74 91 107 124	.084 .099 .100 .110 .123 .154 .191 .224	0.63 0.68 0.73 0.77 0.82 0.92 1.03 1.16 1.23	61 70 78 88 96 119 141 163	.075 .087 .099 .111 .124 .154 .187 .225	2-Stage
450 500 .550 600 650 700 750 800 850 900 950 1000	2.08 2.19 2.30 2.41 2.52 2.64 2.76 2.88 2.97 3.07 3.18 3.28	74 82 88 96 104 111 119 126 133 141	.276 .306 .333 .364 .396 .428	1.74 1.86 1.96 2.05 2.18 2.27 2.37 2.47 2.57 2.67 2.76	107 119 130 141 152 163 174 186 197 208 219	.277 .312 .342 .372 .409 .441 .473 .508 .542	1.48 1.56 1.68 1.78 1.87 1.96 2.06 2.15 2.24 2.33 2.40	157 174 191 208 226 240 258 275 292 308 325	.282 .312 .349 .358 .388 .416 .450 .480 .512	1.33 1.43 1.52 1.61 1.74 1.81 1.88 1.97 2.06 2.14 2.22	208 230 253 275 297 320 342 364 387 409 431	. 267 . 299 . 329 . 366 . 400 . 427 . 454 . 486 . 519	8-Stage

¹ Sullivan Machinery Co.'s Catalog.

APPROXIMATE CUBIC FEET OF FREE AIR AND WORKING PRESSURE REQUIRED TO RAISE 1 GAL. OF WATER BY AIR LIFT—Continued.

Lift in feet	TEEGUL	KED.	10 1	MAIDI		AU.	OF V	ALE	16 D .	7110				mucu.
The feet	Y:44				60	per c	ent. I	66 <u>1</u>						
50	in	A.	W. P.	Н. Р.	A. C.	W. P.	Н. Р.	A. C.		H. P.	A. C.	W. P.	H. P.	
50	30	0.32	24	. 023	0.28	27	.022	0.23	34	.021	0.20	40	.021	1-Stage
70	50	0.38	35	. 036	0.34	40	. 035	0.29	52	.035	0.26	63	.032	
140 6.61 85 .087 0.56 101 .087 0.50 132 .088 0.46 163 .089 160 0.66 96 .100 0.60 114 .099 0.54 150 .101 0.50 186 .103 180 0.70 108 .112 0.65 127 .112 0.58 168 .114 0.54 208 .109 200 6.74 119 .124 0.69 141 .125 0.62 186 .127 0.58 230 .121 250 0.86 147 .159 0.79 174 .158 0.72 230 .151 0.67 286 .152 300 0.96 174 .192 0.89 208 .179 0.81 275 .181 0.76 342 .184 350 1.05 202 .209 0.98 241 .209 0.89 320 .211 0.84 398 .214 400 1.14 230 .288 1.08 .	60	0.41	40	.042	0.37	47	.042	$\overline{0.32}$	61	.038	0.28	74	.037	•
140 6.61 85 .087 0.56 101 .087 0.50 132 .088 0.46 163 .089 160 0.66 96 .100 0.60 114 .099 0.54 150 .101 0.50 186 .103 180 0.70 108 .112 0.65 127 .112 0.58 168 .114 0.54 208 .109 200 6.74 119 .124 0.69 141 .125 0.62 186 .127 0.58 230 .121 250 0.86 147 .159 0.79 174 .158 0.72 230 .151 0.67 286 .152 300 0.96 174 .192 0.89 208 .179 0.81 275 .181 0.76 342 .184 350 1.05 202 .209 0.98 241 .209 0.89 320 .211 0.84 398 .214 400 1.14 230 .288 1.08 .	70	0.46	52	.056	0.42	61	.050	0.36	78	. 049	0.33	96	. 050	
200 6.74 119 .124 0.69 141 .125 0.62 186 .127 0.58 230 .121 250 0.86 147 .159 0.79 174 .158 0.72 230 .151 0.67 286 .152 300 0.96 174 .192 0.89 208 .179 0.81 275 .181 0.76 342 .184 350 1.05 202 .209 0.98 241 .209 0.89 320 .211 0.84 398 .214 400 1.14 230 .238 1.08 275 .241 0.98 364 .242 0.93 453 .247 450 1.23 258 .269 1.17 308 .272 1.07 409 .275 1.02 509 .282 500 1.32 286 .299 1.26 342 .304 1.15 453 .343 <	120 140 160	0.56 0.61 0.66	74 85 96	.074 .087 .100	0.52 0.56 0.60	87 101 114	.075 .087 .099	0.46 0.50 0.54	114 132 150	.076 .088 .101	0.42 0.46 0.50	141 163 186	.076 .089 .103	2-84
250 0.86 147 .159 0.79 174 .158 0.72 230 .151 0.67 286 .152 300 0.96 174 .192 0.89 208 .179 0.81 275 .181 0.76 342 .184 350 1.05 202 .209 0.98 241 .209 0.89 320 .211 0.84 398 .214 400 1.14 230 .238 1.08 275 .241 0.98 364 .242 0.93 453 .247 450 1.23 258 .269 1.17 308 .272 1.07 409 .275 1.02 509 .282 500 1.32 286 .299 1.26 342 .304 1.15 453 .306 1.09 565 .308 550 1.42 328 .385 1.42 409 .365 1.31 543 .369							.112	0.58	168	.114	0.54	208		
300 0.96 174 .192 0.89 208 .179 0.81 275 .181 0.76 342 .184 350 1.05 202 .209 0.98 241 .209 0.89 320 .211 0.84 398 .214 400 1.14 230 .238 1.08 275 .241 0.98 364 .242 0.93 453 .247 450 1.23 258 .269 1.17 308 .272 1.07 409 .275 1.02 509 .282 500 1.32 286 .299 1.26 342 .304 1.15 453 .306 1.09 565 .308 .308 .565 .308 .306 1.09 565 .308 .306 1.09 565 .308 .308 .306 1.09 565 .308 .308 .306 1.09 .565 .308 .308 .308 .306 1.09 .565 .308 .308 .306 1.09 .565 .308 .308 .308 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>														
450 1.23 258 .269 1.17 308 .272 1.07 409 .275 1.02 509 .282 500 1.32 286 .299 1.26 342 .304 1.15 453 .306 1.09 565 .308 550 1.42 328 .338 1.34 375 .334 1.25 498 .343 <t< td=""><td>300</td><td>0.96</td><td>174</td><td>. 192 . 209</td><td>0.89 0.98</td><td>208 241</td><td>.179 .209</td><td>0.81 0.89</td><td>275 320</td><td>.181 .211</td><td>0.76 0.84</td><td>342 398</td><td>.184 .214</td><td></td></t<>	300	0.96	174	. 192 . 209	0.89 0.98	208 241	.179 .209	0.81 0.89	275 320	.181 .211	0.76 0.84	342 398	.184 .214	
700 1.68 398 .428 1.60 476 .432 1.47 632 .435	450 500	1.23 1.32	258 286	. 269 . 299	$1.17 \\ 1.26$	308 342	.272 .304	1.07 1.15	409 453	. 275 . 306	1.02 1.09	509	. 282	2
700 1.68 398 .428 1.60 476 .432 1.47 632 .435	550	1.42	328	.338	1.34	375	.334	1.25	498	343	• • • •	• • •	••••	3
700 1.68 398 .428 1.60 476 .432 1.47 632 .435	650	1 . 51 1 . R1	370	. 300	1.42	442	. 401	1.39	587	. 402				Ž
750 1.78 425 .463 1.66 509 .458 1.55 677 .468 800 1.86 453 .494 1.75 543 .493 1.65 721 .507 850 1.93 481 .523 1.82 576 .523 1.70 766 .533 900 2.00 509 .552 1.86 610 .544 1.77 811 .564 950 2.08 536 .584 1.99 643 .591 1.85 855 .599	700 -	11.68	398	. 428	1.60	476	.432	1.47	632	.435				••
850 1.93 481 .523 1.82 576 .523 1.70 766 .533 900 2.00 509 .552 1.86 610 .544 1.77 811 .564 950 2.08 536 .584 1.99 643 .591 1.85 855 .599		1.78	425	.463	1.66	509	.458	1.55	677	.468			••••	•
900 2.00 509 .552 1.86 610 .544 1.77 811 .564 950 2.08 536 .584 1.99 643 .591 1.85 855 .599		1.80	403	.494	1.75	570	.493 592	1.00	788	533	• • • •	• • •	••••	
950 [2.08[536].584[1.99[643].591[1.85[855].599]				552	1.86	610	.544	1.77	811	. 564				
1000 [2.17]565[.618]2.06[677].622[1.93[900].634[950	2.08	536	. 584	1.99	643	. 591	1.85	855	. 599				•
	1000	2.17	565	.618	2.06	677	. 622	1.93	900	. 634	••••	• • •	••••	

VOLUMERIC	·q1	Alti-	Barom. per sq. ii	Sea 1,000 14.72 1 2,000 13.64 0 3,000 13.13 6 4,000 12.64 0	5,000 12.17 6,000 11.71 7,000 11.27 8,000 10.85 9,000 10.45	10,000 10.06 11,000 9.69 13,000 8.98 14,000 8.98 15,000 8.32
TEFRIC		70	.q.H .neco	0.98000	0.90 0.90 0.88 0.86 0.85 0.85	00.830
AND		_	Volum, coeff.	82228	33822	2588832
H		88	H.p.	1.00 0.98 0.96 0.95	0.08 0.88 0.88 0.88 0.88 0.88	0.83 0.79 0.77 0.77
REEPOWER			Volum.	1 00 0.97 0.94 0.91	0.82 0.79 0.77 0.77	0.657 0.657 0.657 0.653
	Terminal	 .	.q.H neco	0.98 0.98 0.94 0.93	0.89 0.87 0.85 0.85	0.82 0.77 0.77 0.74 0.74
COEFFICIENTS		06	Volum,	1.00 0.97 0.94 0.91 0.88	0.085	000000
	gago promura,	Ĩ	H.p.	1.00 0.98 0.94 0.92	00.89	00.08 00.72 74.73 74.73
FOR T	spunod 's	001	Volum.	1 00 0.97 0.94 0.91 0.88	0000 8200 770 770 770 770	0.067
TWO-STAGE	Per	15	.H.p.	0.98 0.98 0.94 0.94	0.00 0.88 88.88 0.83 88.88	0.81 0.79 0.78 0.76 0.74
GE AIR	aquare inch.	120	Volum.	1.00 0.97 0.93 0.90 0.87	0.082 0.73 0.75 5.73	0.088 0.088 0.098 0.098
1		11	.q. H .Bace	1.00 0.98 0.96 0.94 0.92	00000 0888 888 888 888 888	0.75 0.75 0.75 0.75 0.75 0.75
COMPRESSION ¹		40	Volum. Beco	1.00 0.97 0.93 0.90 0.87	0.81 0.78 0.78 0.73	0.71 0.68 0.68 0.63 0.59
ION		1	.q.H .lleoo	1 00 0.98 0.96 0.94 0.94	0.00 0.00 0.88 8.89 8.89 8.89	0.75 0.75 0.75 0.75
		150	Volum.	1.00 0.97 0.93 0.90 0.87	0.84 0.78 0.78 0.76 0.73	0.000.000

Bullivan Machinery Co.'s Catalog.

Horrepower pre 100 Coric Feet Free Air Per Minute, Two-stage Compression; Tezoretical Horsepower in Air Cylinders!

(Allow for Friction and other Louses)

Altitude	Barom.					Tel	minal g	Terminal gage pressure	ean				
in feet	aq. in.	5	7.5	88 /	88	0,6	96	100	110	120	130	140	150
Sea level 1,000 3,000 4,000	14.72 13.64 13.13 12.64	12.84 12.62 12.33 12.17	13.32 12.84 12.64 12.37	13.78 13.52 13.27 13.03 12.78	14.21 13.95 13.68 13.43 13.17	14.63 14.35 14.08 13.81 13.54	15.03 14.74 14.46 14.18 13.90	15.42 16.12 14.82 14.53 14.25	16.15 15.83 15.51 15.20 14.90	16.83 16.49 16.15 15.83 15.80	17.47 17.11 16.76 18.41 18.07	18.07 17.69 17.33 16.96 16.61	18.25 17.86 17.86 17.48 17.11
98,49.50 90,000 90,000 90,000	12.17 11.27 10.85	11.72 11.51 11.29 11.07 10.87	12.14 11.91 11.68 11.46 11.24	12.30 12.30 12.06 11.83 11.59	12.92 12.66 12.41 12.17 11.93	13.28 13.02 12.76 12.50	13.85 13.35 13.09 12.82 12.57	13.96 13.40 13.13 12.86	14.80 14.29 14.00 13.71	15.19 14.86 14.55 14.25 13.95	15.74 15.40 15.07 14.75 14.44	16.25 15.90 15.22 14.90	16.75 16.38 16.02 16.02 15.67 15.33
1000 112,000 14,000 16,000	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	10.66 10.25 10.05 9.85 9.85	11.02 10.81 10.59 10.38 10.17 9.97	11.37 11.14 10.92 10.70 10.48 10.48	11.69 11.46 11.22 11.00 10.77	12.01 11.76 11.28 11.05 10.83	12.31 12.06 11.56 11.31 11.31 1.31	12.68 12.34 11.83 11.57	13.14 12.87 12.60 12.32 12.06 11.79	13.65 13.36 13.07 12.79 12.51	41 82 82 82 82 82 82 82 82 82 82 82 82 82	14.57 14.26 13.94 13.32 13.32	14.99 14.34 13.70 13.39

1 Sullivan Machinery Co.'s Catalog.

Air Lifts—Ratio of Lift to Submergence¹

Lift	Submergence
Up to 50 ft.	70-66 per cent.
50–100 ft.	66-55 per cent.
100–200 ft.	55-50 per cent.
200–300 ft.	50-43 per cent.
300–400 ft.	43-40 per cent.
400-500 ft.	40-33 per cent.

METALLURGICAL CONSTRUCTION

Allowable Unit Strains For Metallurgical Works² Substructure

Foundations.—Pressure on foundations not to exceed, in tons per square foot:

Soft clay	1
Ordinary clay and dry sand mixed with clay	2
Dry sand and dry clay	3
Hard clay and firm, coarse sand	4
Firm, coarse sand and gravel	6

Masonry.—Working pressure in masonry not to exceed, in tons per square foot:

10
12
15
8
10
12
20
25
30
20
25

Pressure on Wall-plates.—The pressure of beams, girders, wall-plates, column bases, etc., on masonry shall not exceed the following, in pounds per square inch:

On brickwork with cement mortar	200
On rubble masonry with cement mortar	200
On Portland-cement concrete	350
On first-class sandstone	400
On first-class limestone	500
On first-class granite	600

<sup>Sullivan Machinery Co., Bull. No. 71-A.
"Specifications for Structural Work on Buildings," A. S. M. E.</sup>

Costs of Some Metallurgical Plants¹

Character of plant	Capacity per 24 hours	Cost
Iron blast furnace	300 tons of pig iron	\$650,000 900,000
las and hot-metal reservoir.		•
Acid open hearth, ten 50-ton furnaces.	1000 tons of steel	1,500,000
Basic open hearth, ten 50-ton furnaces.	1000 tons of steel	1,650,000
Rolling mill	Starting with ingots 20 in. square, weighing about 5000	1,250,000 to
•	lb., consisting of 36-in. bloom- ing mill and 28-in. structural mill.	1,500,000
Copper smelting and converting.	Partial pyritic smelting of 1000 tons of ore to 100 tons of 45 per cent. matte.	1,250,000
Lead smelting	500 tons of mixed lead ore	250,000
Parkes desilverizing	100 tons of lead bullion	250,000
Moebius electrolytic parting	30,000 oz. of doré bullion	20,000
Electrolytic copper refining, multiple process.	100 tons of copper, from pig to wire bars.	500,000
Zinc smelting	100 tons of blende, not making sulphuric acid.	375,000
Stamp milling ²	100 tons per day	50,000
Stamp milling ²	100 tons per day	100,000

Cost of Metallurgical Work³

Cheapest type of mill in Joplin district, capacity 50,000 tons annually, construction cost, 12 to 16 cts. per ton of annual capacity.

Joplin mill designed for concentration of mixed sulphide ore,

15,000 tons annual capacity, 67 to 80 cts. per ton.
San Juan mill, capacity 75,000 tons per year, cost per ton **\$**1.33.

Wet concentration mills of Boston Consolidated Copper Co.,

1,000,000 tons capacity, cost about \$1.50 a ton.

Garfield mill of Utah Copper Co., capacity 2,200,000 tons, cost per ton \$1.85.

Ohio Copper Co., capacity 1,000,000 tons, cost per ton \$1.50.

The above are for wet concentrating mills.

Magnetic Separating Plants

New Jersey Zinc plant, 300,000 tons capacity, cost \$1.75 per ton. Smaller plants are 15,000 tons capacity, cost \$3 to **\$4** a ton.

Copper Smelting Works

Blast-furnace plant, no roasting furnaces, annual capacity 330,000 tons, $\cos t$ \$1.70 per ton.

Balakalala, capacity 437,500 tons, cost \$2.25 per ton, of

which 25 cts. was for the converter plant.

Washoe plant, capacity 3,000,000 tons, cost \$3.56 per ton.

1 HOFMAN, "General Metallurgy," p. 888.

3 H. A. MEGRAW, private notes. *By W. R. Ingalls in Engineering and Mining Journal, July 2, 1910.

CONSTRUCTION COSTS, BELMONT MILL

	Excavation,	Floors and	Buik	Buildings	Machinery, including	e de de la companya d
	concreve wans, and foundations	foundations	Frames	Covering	piping, wiring, belting, etc.	1000
		. 02 100 04	02 000 00	OF OUR PE	901 121 00	F0 041 600
Inclined conveyor	166.41	238.02	1,771 75	80 0/4,16	3.620 79	6.382.16
bins	399.00	489 70		2,067.69		6,431 53
Stamps		20,797			_	45,670.88
Calma and Castinette.		0,100 H0			-	43,500 54 889 65
Concentrative plant					_	13.019 58
Concentrate house	76.80		354.80	623 27		2,106.66
Dom thickenors						26,332 51
Circulating system	0.00	0 007 00			_	90,893,86
Charfenge						10 403 50
Precipitation system.	895.00	44 05				30,020,07
						1,589 49
Air compressor		1,084.39		** ********	-	8,178.91
Filter plant	70 047 0	4,456.68	44 000 0	00 000 0	-	34,561,18
Boiler ofact and fuel-oil evetem.	571.56	76.00	401.25	531.11	7.606.28	9.201.17
Tank-beating system.		9 26				3,371 95
Transformer house	91.83	101.05	428.69		_	5,639 53
:	1 207 66	843.01	1 138 79			4.810.45
Btoreroom	511.55	1,500.60	1,305 84	1,315 78		4,794.81
Inclined railway	133.25				_	1.148.87
Kill building	39,645.45	6,757 60	45,493.48	19,607.14	_	
Total	\$51,795.78	\$51,085.37	\$55,758.13	\$30,861.38	\$275,688.41	8465,189.07

Highland Boy plant, capacity 300,000 tons, cost \$3.23 a ton. Garfield plant, capacity 800,000 tons, cost \$7.50 per ton, but this included a large amount of land secured to protect against smoke suits.

Lead Plants

Modern lead smelting works, capacity 330,000 tons, cost \$2.30 to \$3.00 per ton. A lead desilverizing refinery, capacity 30,000 tons of base bullion, cost about \$6.66 per ton.

Zinc Smelting Works

Zinc smelteries in natural gas field in Kansas and Oklahoma, capacity 25,000 tons annually, cost \$7.00 per ton.

Plant in the same field, of superior design and construction,

cost \$10.00 per ton.

Plant to burn coal with gas producers and regenerative furnaces in Europe, figured to cost \$15 per ton. Same plant in United States would probably have cost \$17.50 to \$18.00, but actual constructions have run as high as \$20.00 per ton.

Sulphuric Acid Works

Sulphuric acid plant, to be added to zinc smeltery, cost in 1914, \$5 to 6 per ton of H₂SO₄. As the ore usually contains about 32% S, the statement also applies per ton of ore.

Miscellaneous

Tennessee Copper Co., acid plant, annual capacity 168,000 tons of acid, cost per ton of capacity \$10.00.

Randfontein Central mill, capacity 150,000 tons per month,

cost per ton \$4.80.

Moctezuma, capacity 2000 tons per day, cost \$1.37. Federal Lead, capacity 2400 tons per day, cost \$1.03.

Southeastern Missouri in general, \$1.26.

Wetherill magnetic separating plant, capacity 100 tons per day, cost \$2.05.

Blake electrostatic, capacity 100 tons per day, cost \$1.37.

Wilfley roasting process, capacity 100 tons per day, cost \$1.37.

Mexico silver-gold cyaniding plant, \$3.40 per ton.

Cyanide Plant Construction

Bearing out the estimate of \$1000 per ton of daily capacity as the cost of constructing a cyanide plant, the figures on p. 464 were given in the A. I. M. E. Bulletin for September, 1915.

The general subject of mill construction costs for the amateur was covered by HARRY T. CURRAN in the Engineering and Mining Journal of Aug. 14, 1915, so well that there seems to be nothing to add to his article, which is herewith reproduced.

Mill-construction costs are widely variable and the subject is a broad one. No two mills are alike, nor will their construction be carried on under the same conditions, yet the construction work itself is much the same in all. The figures given in this article are taken from my field notes and by modification they can be applied to any similar work.

The results of laborious search into metallurgical literature for mill-construction data are discouraging at the best. Little has

been written on the subject, and the operator is prone to place too much reliance on "general figures," which in varied modern practice comprise the last word in unreliability. General figures are useful, however, in rough preliminary estimations. it has been determined just what kind of a plant is needed, the site selected and drawings made, a thorough organization of plans should be established and every detail gone over in the mind's eye.

Preparation of Costs of Material.—The first step is to estimate the yardage to be excavated, the amount of masonry or concrete work required, and then a complete list of all material The tendency is to overlook a multitude of should be made. small things which have considerable value in the aggregate. To the machinery specifications should be added a complete list of lumber, doors, windows, all hardware down to nails, pulleys, belts, lime, sand, broken rock—in fact everything that goes into the construction. The cost and weight of this can readily be determined by consulting reliable dealers and adding the necessary freight charges.

Planning the Preliminary Work.—The next step should be the working out of a thorough development plan and an estimate of its cost. Everything should be made ready, so that when actual construction starts there will be neither confusion nor delay. The cost of this work is considerable and it is often neglected, with the consequent addition of excessive costs to some other part of the work. A great amount of future trouble and worry can be avoided by a careful planning for a few impor-

tant features, which will be mentioned.

Unloading facilities and material and tools to do it with should be provided. A good road to the plant should be built and convenient deliveries arranged for. It is a noticeable fact that many a well-constructed mill has such poor facilities for receiving supplies that the extra cost for a year would probably build everything needed to make such work easy and cheap. room ought to be set aside for timber yards; and all lumber should be marked and piled so that a glance will determine just what part of the job it was bought for.

A handy place should be marked off for a storage house and its cost estimated. It is surprising what a number of small things will be lost or misplaced without such storage. Roomy framing plots, as level as possible, should be marked off and handy places for machinery storage determined, keeping in mind pieces which will be first used and their situation. supply of gravel, sand and rock must be looked into and arrangements made for its cheap delivery at any point. All details for disposing of rock and earth excavated with the least possible amount of handling should be planned.

The labor question must be studied and complete arrangements made for the comfort of the men. Their efficiency will vary directly with the conditions of their surroundings. cently, in the West, a so-called mining man who had never given human nature a moment's thought attempted to build a mill in

an out-of-the-way place with no fit accommodations for anyone but himself. The results were disastrous for the company. Good men could not be kept and the mill was finished up at an excess in cost of more than \$50,000. Some of the tanks collapsed on their foundations with the first filling.

The cost of all this preliminary work can be estimated by the man on the ground; it averages from 5 to 10 per cent. of the total. If it is neglected, confusion and delays throughout the job are the inevitable result. Good organization is just as essential to

the construction of a plant as to its operation.

Consideration of Erection Costs.—Erection costs are variable and can only be obtained by experience or by comparison with other jobs. If all necessary steps are taken to avoid delays estimates can be made dependable within reasonable limits. Fixed rules cannot be given for this part of the work. They will vary with the wages, efficiency of labor, climatic conditions and the experience of the man in charge. However, if the rules given in this article are applied for summer work in the United States, the estimate will come approximately close to actual cost. Labor wage is based on the average paid in Western mining

camps.

Superintendence can be figured when conditions are known, and will average, including cost of plans, from 3 to 5 per cent. of the total. Excavation by picking, shoveling, and hauling average earth in wheelbarrows, moving 100 ft., will cost about 45 cts. per cubic yard; add one-third of hourly wage of laborer for every additional 100 ft. Where mine cars can be used to advantage this may be cut to 35 cts. per cubic yard, moving 100 ft.; add one-fifth of hourly wage for every additional 100 ft., which covers placing the track. Breaking rock by hand—like hauling conditions—will cost from \$1.25 to \$1.75 per cubic yard, with 100 ft. haul. It will cost a few cents more per yard than in earth work for every additional 100 ft. There are so many unknown quantities entering into excavating that these figures

are only roughly approximate.

Masonry and Concrete Construction.—Rubble masonry will average \$5 per cubic yard, using cement mortar. A mix of 1 part of portland cement to 5 parts of sharp, clean sand will give good results. Such walls will average about 15-in. courses and will require from 1/4 to 1/3 cu. yd. of mortar per cubic yard of wall. Concrete work can be figured to a nicety when conditions are known. With a mechanical mixer \$1 a yard will cover the cost of mixing and placing in the average mill. On a large job it is well to determine just what mix is required with the material used. The duty of the sand is to fill the voids in the broken rock and, when the two are mixed, the resultant voids should be filled with cement. It is well to allow 10 per cent. excess in each case, but there is nothing gained by using a richer mix for retaining walls and foundation. However, if a weaker mix is desired it can be obtained by puddling instead of cutting down the proportion of sand and cement. In forms of any size puddling is good practice and the strength of the concrete is by no means decreased. Clean, firm rock should be used and the edges should not touch. On the average mill job concrete will not cost more than \$7 per cubic yard for large forms, \$8 for medium, and \$10 for small and heavy-duty machine foundations, including the cost of the forms. By using old iron, reinforced concrete can be made for 50 cts. per yard more. Floors with a 5-in. base and 1-in. covering will average

from \$10 to \$14 per cubic yard.

Unloading and hauling depend upon conditions. There will be a fixed average charge of from 30 cts. to 40 cts. per ton. Small pieces should be handled for less, but large unyielding pieces, such as a tube mill, can easily cost to \$1 per ton. Probably 75 cts. per ton-mile would be a good average for hauling on any kind of a decent road and grade. By consulting local freighters these things can be definitely settled. The accompanying curve shows the variable cost of hauling on different grades. For example, consider 50 cts. per load as a cost unit, representing a reasonable cost per mile on level roads, so that a comparison of costs on different grades can be found.

Carpenter work with a well-organized crew of mill-wrights will average about \$21 per M, for framing and erecting; \$12 to \$15 per M, for siding and roofing and \$2.50 per M for shingles or 75 cts. to \$1 per square for corrugating iron roofing and siding. With a picked-up local crew, \$28 to \$31 per M, for framing and erecting, \$19 per M, for siding and roofing and \$2.50 per M for shingles or \$1.25 per square for iron, will be the average figures. The nails required in this work per M will be about as shown in

the table.

NAILS REQUIRED IN ERECTION

	D	Lb.
Siding and roofing. Flooring (1-in. material). Flooring (2-in. material). Studding, etc. Shingles (per 1000).	8 8 20 or 30 10 4	18-21 28-32 20-25 14 6

Assembling and erecting machinery depends upon the nature of the machinery. A good point to emphasize here is that poorly stored machinery may easily add several dollars per ton to erection costs. An experienced engineer will size up the job and divide the material into different classes. It is then usually figured on a tonnage basis. Generally speaking, the heavier the piece the less the erection cost per ton. Steel tanks over % in. thick can be erected for \$35 per ton; for % in. or less from \$40 to \$45 per ton. To place engines, stamps, crushers, pumps, to line up shafting, set electric motors, including wiring, etc., about \$45 per ton of iron. To set up concentrating machinery, classifiers, filters, etc., from \$50 to \$65 per ton. These figures cover the necessary carpenter work, placing pulleys, belts, and

adjustments. When the carpenter work is figured separately, these figures are high. Under these conditions it will cost from \$25 to \$30 per ton of iron to place engines, stamps, crushers, lineup shafting, etc. To set up concentrating machinery, classifiers, filters, etc., from \$30 to \$45 per ton. This of course includes placing pulleys, belts, and adjustments. The pipe work in the average mill will cost from \$40 to \$45 per ton. Erecting wooden tanks costs about \$12 per M. Reduction works constructed wholly of steel are now becoming popular where the winters are not too severe. Framework of steel can be erected for \$12 to \$15 per ton by contract. A good contractor with a crew of construction men will make money at these figures. However, the amateur will do well if he shades the figures at all.

Recently the construction of a 50-ton combination concentrating and cyanide plant came under my notice. The contract was taken for just a little under \$30 per M, and the same price per ton for machinery erection, which also included all foundations and concrete work. The total cost of the mill was around \$30,000, but it is just under a finished product in every way and is bound to give considerable trouble that will eventually cost more, not considering delays, than the extra thousand or two dollars it would have taken to make it a

finished mill in the first place.

Small items are important and there are a number of them. Considerable timber is required for staging and a number of unavoidable losses must be allowed for. The building should be painted, fire protection and heating arranged and office and

laboratory equipment bought.

Cost of Making Alterations.—The expense of the breaking-in period and necessary alterations are often overlooked. Here we have the personal equation entering. It is a bet by the designer and constructor on his own ability. It is a good idea to allow 10 per cent. of the total cost for possible changes, while any excess is often useful to cover the expense of unavoidable delays. I have in mind two mills, designed by two well-known metallurgists, where the starting-up period took in one case 5 per cent. of the total expenditure and 15 per cent. in the other. The operator has a problem different from that of the man who follows construction only. When the former designs and constructs a mill he must worry through the breaking-in period and come out with a mill that is satisfactory in every way. On the other hand, the construction man generally has a contract and his responsibility ends by turning over a mill that is up to specifications, which may mean a good mill or a very poor one from the operator's standpoint.

Difficulties of Winter Construction.—In the northern United States winter work is a tough undertaking at its best and should be avoided if possible. With an average winter the excess cost will easily foot up to 33 per cent. of the total labor expenditure. With an open, mild winter these figures are high, but with a cold, snowy winter they may easily reach 50 per cent. Concrete

work often costs 35 per cent. more, as complete arrangements must be made for heating and protecting against frost until after the preliminary set. After 12 hours, freezing can only retard

the final set, but cannot injure the concrete.

A brief description of methods used in a winter concrete job may be of interest. A steam coil 12 × 12 ft. was made out of 2-in. pipe spaced 1 ft. apart, and perforated every 6 in. with 3/16-in. holes. This made it possible to keep plenty of broken rock heated ahead of the mixer. Barrels were arranged on the mixer platform so that the water could be heated to the boiling point with steam. A 10 per cent. salt solution was made, which in no way seemed to damage the concrete. The sand was not Live steam was turned into the forms before pouring, sufficient time being allowed to draw the frost a few inches. Large forms were simply well covered with canvas after filling; the concrete stayed above the freezing point for a couple of days even in the coldest weather. Small forms were protected by steam hose and fires for 12 hours. Calcium chloride is probably better than sodium chloride, since its solution freezes at a lower temperature and it also increases the waterproof quality of the concrete. It has been proven that concrete with 2 per cent. of calcium chloride gives the best resistance. More than 2 per cent. of it unduly increases the speed of setting and weakens the concrete. Since from 10 to 15 per cent. of water is used in mixing concrete, a 2 per cent. mix would be given by using a 15 or 20 per cent. solution. A 20 per cent. sodium-chloride solution freezes at about 7°F., while a 20 per cent. calcium-chloride solution will not freeze until it reaches about the zero mark.

On a winter job of any size an inclosed framing shed will pay for itself many times over. It is not only useful during the framing period, but is a happy addition on a bitter cold day during the erecting period when the carpenters would otherwise have to be laid off. There are always launders, doors, plate beds, or a multitude of small things that they can work at under protection from the weather. When the mill is finally under cover it can be kept comfortable and the work will go on much

more efficiently.

Expense of Rebuilding Old Mills.—Remodeling old mills is in a class by itself and each case presents a special problem depending upon the extent of the work and the condition of the mill. Like a new mill the cost of excavating, concrete, machinery, etc., can be rather accurately figured on, but the amount of hardware and lumber that can be used again and the amount of new material required is often misleading. The carpenter work and assembling of machinery will generally cost twice as much as in a new plant. It is a tearing down and building up process for which no rules can be given.

The main causes for underestimates are:

Guess work, lack of good organization, false economy, omissions and change of plans, neglect of preliminary work, too much reliance placed on general figures, and inefficiency of labor resulting from surroundings. Under unavoidable circumstances

ULTIMATE AND ELASTIC STRENGTES OF MATERIALS 1

	Uldins	Utimate etrength (V)	(2)	Elestic	Electic strength (E,L)	(E. L.)	Direct coefficient of	Transverse coefficient of
Material	Tenajon	Comp.	Shear	Tension	Comp.	Shear	elasticity (E)	elasticity (Es)
Cast iron	20,000	95,000	20,000	10,0001	25,000	8,000	15,000,000	6,000,000
Malleable iron	35,000	45,000	20°04 00°04	30.000	28,000	22,000	:8	10.000.000
Steel, 0.15 carbon.	63,000		48,000	42,000	40,000	:	30,000,000	10,000,000
_	80,000		57,000	48,000	46,000		Š	10,000,000
Steet, 0.70 carbon	89,000		90,00	53,000	53,000		g	10,000,000
Steel, 0 80 carbon	103,000		80,000	57,000	63,000		g	10,000,000
Steel, 0 96 carbon.	118,000		83,000	69,000	71,000		8	10,000,000
Steel, boiler plate	60,000		48,000	30,000	:		g	
Crucible steel	116,000			80,000	80,000	•	g	12,400,000
Steel castings	20,000		40,000	30,000	30,000	•	8	
Nickel steel	100,000			60,000			31,000,000	
Copper castings	22,000	60,000	:	000,			12,000,000	:
Rolled copper	31,000	:	* * * * * *	6,000		:	15,000,000	
Brass castings	20,000	12,000			;		10,000,000	*
Bronze, gun metal	35,000	:		:			12,000,000	:::::::::::::::::::::::::::::::::::::::
Bronze, phosphor	50,000	•	4	30,000			14,000,000	:
Tobin metal	80,000			55,000				•
Aluminum castings	15,000	12,000	12,000	6,500	3,500	:	11,000,000	:

Prescand Carves's, "Tables for Engineers" See also p. 473.

may be mentioned unexpected strikes or inefficient labor, badweather delays and the failure of railroads or supply houses

to deliver material as expected.

Any reputable machinery house will give valuable information. Nearly all have one or more experienced engineers and will gladly go into all details with the buyer. It is a mistaken idea to think that they let their responsibility end with the last car of machinery that leaves their plant. There are plenty of would-be metallurgists who are always willing to build a plant for half the bid of a reputable house, but without exception they are a most expensive "economy." This also applies to the manuacturer of an untried innovation. Almost without exception a small mining company cannot afford to experiment with such things. If there is merit in the innovation the larger companies will soon pick it up and demonstrate it. If the plans are followed, a good organization maintained and efficient labor secured, the figures will be found a little higher than actual costs. Sectionalized machinery for mule-back haulage cannot be erected at these prices.

Effectiveness of Wood Preservatives

The relative efficiencies of certain widely used wood preservatives were recently tested by the U.S. Department of Agriculture (Bull. No. 227).

The tests were made by the Petri-dish method. The quantities mentioned are sufficient to stop growth in a cubic foot of

culture medium.

For Fomes annosus	Pounds	For Fomes pinicola	Pounds
Coal-tar creosote: Fraction II. Sodium fluoride Cresol calcium Coal-tar creosote: Fraction II. Zinc chloride. Coal-tar creosote, Grade C. Water-gas tar distillate (sp. gr. 0.995) Wood creosote Hardwood tar Coal-tar creosote: Fraction IV. S. P. F. carbolineum Avenarius carbolineum Coal-tar creosote: Fraction V. Copperized oil. United Gas Improvement Co., 1.07 oil. Nonesuch special Sapwood antiseptic.	0.14 0.16 0.09-0.18 0.19 0.20 0.31 0.34 0.41 0.78 2.06 2.8 3.27 20.59 25.0 Over 25 Over 25 Over 25 Over 25	Coal-tar creosote: Fraction III	0.08 0.08 0.09 0.09 0.13 0.14 0.14 0.19 0.47 0.47 4.87 Over 25 Over 25 Over 25

CEMENT COMPOSITIONS

	SiO ₂	Al ₂ O ₂	Fe ₂ O ₃	CaO	MgO	SO:	NaKO
Portland ¹	28.95 21.60	4-11 7.14 11.40 3.20 9.30- 12.70		58-67 35.98 50.29 61.00 50.80- 55.00	18.00 2.96 0.85 0-3.00	0.60	

STRENGTH OF COMMON MATERIALS⁴

400 40 50	12,000 1,000 1,000
40 50	1,000
50	1,000
	,
300	2,000
400	2,000
500	3,000
200	1,000
400	2,000
	4,000
t t	7,000
	6,000
	8,000
000	5,500
1 1	500 200 400 000 000 000 000

BLOWING MACHINERY TYPES

The centrifugal blower is usually used for moving large volumes of air at pressures up to 16 oz. per square inch. Such service is that required for reverberatory furnaces or cupola furnaces. The disadvantages of the centrifugal blower are that it must run very close to rated capacity if it is to run economically, and that it cannot send blast into a choked furnace. An example of a large centrifugal blower is quoted by HOFMAN as being furnished by the General Electric Co., 10,200 cu. ft. of air per minute at 3½-lb. pressure.

Turbo-blowers are multistage centrifugal blowers. The discharge from one blower forms the feed of the next, thus enabling these blowers to compete even with high-pressure blowing engines. Hofman quotes one blowing 42,000 cu. ft. of air per minute, attaining a maximum pressure of 18 lb.

BENSON'S, "Industrial Chemistry." The Macmillan Co. J. PARK, "Text-book of Practical Assaying." Said to be finest natural cement in the world.
4 PIERCE and CARVER'S, "Tables for Engineers."

Rotary Blowers.—Two impellers, which may be similar or dissimilar in shape attached to parallel shafts, revolve in opposite directions. The impellers are in tangential contact with each other and with the casing and hence draw in a fixed volume of air and discharge it on the opposite side. Consequently they are known as positive blowers. They are most effective working at from 1 to 4 lb. pressure. The Roots blower has two impellers whose surfaces are epicycloidal curves. The Conners-ville also has this impeller form. The Baker has one large impeller with two vanes, and two small revolving drums for valves. The Sturtevant is a very complicated two-impeller machine.

Blowing Engines.—These are of the double-acting piston type and are used for converters, iron blast furnaces, and a few

copper furnaces requiring very high pressures.

Testing Blower Capacity

Experiments at the Mission School of Mines by Elmo H. Harris have shown that the most reliable method for testing large blowers is by passing the air current through large orifices. A 30-in. orifice will pass about 25,000 cu. ft per min. under 4-in. water pressure. Where very large blowers are to be tested he advises setting several orifices in a conduit wall (Missouri School of Mines Bull., November, 1915). The essential tables are:

	icient in.		Co	efficien	ts C for l	arge orifi	ces .	
Water gage, inches,	il coeffice 3½		Round			Squa	re	
. •	McGill c	30 in.	24 in.	18 in.	30 in. × 30 in.	24 in. × 24 in.	18 in. × ,18 in.	18 in. X 30 in.
1 2 3 4 5	0.599 0.597 0.596 0.595 0.594	0.604 0.602 0.601 0.600 0.599	0.596	0.594	0.626 0.625	0.607 0.605 0.604 0.603 0.601	0.598 0.596 0.595 0.694 0.593	0.602 0.600 0.599 0.598 0.597

The above coefficients are to be applied to get the weight Q per second, of air passing by formula as follows:

For round orifices
$$Q = C \times 0.1639 D^2 \sqrt{\frac{i}{t}p}$$

For rectangular orifices
$$Q = C \times 2.413a\sqrt{\frac{i}{t}p}$$

Q =Weight of air in pounds per second.

i =Water gage in inches.

t =Absolute temperature (Fahrenheit) = 460 +(Thermometer reading F.).

p = Absolute pressure back of orifice in pounds per square inch = barometer pressure + 0.036i.

D = Diameter of round orifice in inches.

a =Area of rectangular orifice in square feet.

SECTION X

GENERAL METALLURGY

PROCESSES KNOWN BY THEIR INVENTORS' OR BY NON-DESCRIPTIVE NAMES

Aczolling—the treatment of timber with a mixture of metallic ammoniates with an antiseptic acid (derivative of phenol or

naphthaléne).

Augustin process for silver extraction consists of chloridizing-roasting; leaching with hot solutions of common salt in wooden vats; precipitating the silver on copper and casting into silver bars; precipitating the copper on scrap iron and casting it into shot to be used again.

Bessemer process—the production of steel by blowing air through molten pig iron. Also, by analogy, the enrichment of copper matte by blowng air through it when molten. See

Converting.

Betts lead refining process—an electrolytic process using PbSiF₆ acidulated with HF as the electrolyte.

Boss process for silver extraction is a continuous pan-amal-

gamation process.

Converting—the process invented by Pierre Mannés in which air is blown through molten copper matte in the presence of free silica. The iron is oxidized to FeO which forms a slag with the silica; the sulphur is oxidized and goes off as SO₂. After the iron is practically oxidized, copper is formed thus:

$$Cu_2S + 3O = Cu_2O + SO_2$$

 $2Cu_2O + Cu_2S = 6Cu + SO_2$.

Also applied to the Bessemer process of steel manufacture.

Diehl process—a modification of the cyanide process in which cyanogen bromide is added to the leaching solution.

Dumoulin process—copper is deposited on a rotating mandrel and this copper is later stripped off as a long strip, which is then drawn into wire without recasting.

Elmore process—a flotation process. See Flotation for full

description.

Gutzkow's process—a modification of the sulphuric-acid parting process for bullion containing large amounts of copper. A large excess of acid is used; the silver sulphate is then reduced with charcoal or, in the original process, ferrous sulphate. Hayden process—for copper refining. There is but one

Hayden process—for copper refining. There is but one true cathode and one anode in the tank, a large number of plates of unrefined copper being placed between and parallel

to them. The side of each plate toward the cathode then acts as anode, while copper is deposited on the side of each plate toward the anode, until the entire plate has moved over by the amount of its own thickness. This is the so-called series method of refining.

Höpfner process—Copper Recovery.—A solution of cuprous chloride in sodium or calcium chloride is used to dissolve copper sulphides. The solution is then electrolyzed in tanks with diaphragms. The anodes are copper, the cathodes pure copper. Copper is deposited from the cuprous-chloride solution, and

cupric chloride regenerated.

Hunt's process—compiled by Bertram Hunt for treating precious metal ores containing copper or zinc, using an ammoniacal cyanide solution and recovering ammonia by boiling. Process may more truly be said to have been devised and

perfected by Mosher.

Hunt & Douglas process—consists in roasting matte carrying copper, lead, gold and silver at a very low temperature, forming copper sulphate and oxide but not silver sulphate. This product is leached with dilute sulphuric acid for copper. The resulting solution is treated with calcium chloride and the copper precipitated as subchloride by passing SO₂ through the solution. The cuprous chloride was then reduced to cuprous oxide by milk of lime, regenerating calcium chloride, and the cuprous oxide was smelted.

Kiss process—about the same as the PATERA process (which see below) except that calcium hyposulphite was used for leaching the ore, and calcium polysulphide for precipitating

the silver.

LeBlanc process for soda making—

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl$$

 $Na_2SO_4 + 2C = Na_2S + 2CO_2$
 $Na_2S + CaCO_3 = Na_2CO_3 + CaS$

Lohmannizing—a process by which a protective zinc coating is amalgamated to the base-metal sheet. Details of the process not made public.

MacArthur-Forrest cyanide process—the original successful

commercial process.

Marriner process—a modification of the cyanide process in which the ore is dead roasted, all of it ground to slime, and the resulting product treated by agitation.

Miller process of parting gold and silver by conducting chlorine gas into the molten metal. The silver and other base metals are chloridized and come to the top of the bath.

Moebius process—for parting gold and silver. The electrolyte is silver nitrate with a little nitric acid. In the original process the silver was deposited on an endless moving silver belt, from which it was constantly removed by revolving brushes.

Murex process—see under "Flotation," p. 408.

Parkes process—lead refining by the addition of zinc to

molten argentiferous lead. The zinc and silver rise to the surface of the bath as a scum, which is then taken off and afterward distilled to drive off the zinc.

Patera process consists in a chlorizing-roasting; leaching with water to remove base metals (some silver is dissolved and must be recovered); leaching with sodium hyposulphite for silver; precipitation of silver by sodium sulphide. The process was first carried out by von Patera at Joachimsthal.

Patio process is one for the recovery of silver by amalgamation in low heaps with the aid of salt and copper sulphate (magistral). Thorough mixing is obtained in the usual form

by having horses or oxen tread the mass.

Pattinson process—recovery of the silver from argentiferous lead by fractional crystallization of lead crystals out of a silver-lead eutectic. Seldom used now except in conjunction with the Parkes process (q.v.).

Peirce-Smith—basic-converting process—converting copper matte in a magnesite-lined converter. The iron of the matte

is fluxed by silica added before the process begins.

Pelatan-Clerici process is a continuous process of dissolving silver or gold in cyanide solution and simultaneously precipitating the precious metals in mercury in the same vessel, an electrical current assisting precipitation.

Powellizing—a process of wood treatment consisting in impregnating the wood with a saccharin solution. It hardens

the wood, and appears to fireproof it somewhat.

Randolph process—a modification of the series process of copper refining in which the electrodes lie horizontally, the top surface of each one acting as anode, the lower as cathode. Theoretically it has the advantage of extremely low metal losses and great purity of copper. Practically, it is too difficult to right matters in a tank after a short circuit. See HAYDEN series and SMITH processes.

Reese River process—pan amalgamation with previous

roasting.

Rozan process (Luce-Rozan process)—Pattinsonizing with steam.

Russell process—about the same as the PATERA (q.v.) except that cuprous-sodium hyposulphite is used in addition to the sodium hyposulphite.

Series Copper-refining Process.—See HAYDEN, SMITH and

RANDOLPH processes.

Sherardizing—a galvanizing process in which the metal to be coated is heated, with or without tumbling, in contact with zinc dust. Blue powder or manufactured dust may be used for the source of the zinc.

Siemens & Halske method of copper recovery.—Copper sulphides are dissolved by solutions of ferric sulphate containing free sulphuric acid.

 $(H_2SO_4) + Cu_2S + 2Fe_2(SO_4)_3 = 2CuSO_4 + 4FeSO_4 + (H_2SO_4)$ The solution is then electrolyzed in a tank having a diaphragm. Copper is deposited and ferric sulphate regenerated. Siemens-Martin process—the production of steel in a reverberatory furnace by oxidation of the impurities by oxides added (either the rust on scrap, or mill scale, or pure ores).

It may be conducted either on an acid or a basic lining.

Smith process—a variation of the series system of copper refining in which the plates are placed horizontally, the top surface of each one acting as cathode, the lower as anode. Linen diaphragms must be placed between the plates to catch the slimes. These diaphragms break and allow the slimes to drop on the cathode, and it is impossible to remedy any short circuits in the tank without dismantling the tank.

Solvay process for soda manufacture—

 $NaCl + HNH_4CO_3 = HNaCO_3 + NH_4Cl$ $2NH_4Cl + MgO = MgCl_2 + 2NH_3 + H_2O$ $2HNaCO_3 = Na_2CO_3 + CO_2 + H_2O$ $CO_2 + NH_3 + H_2O = HNH_4CO_3$.

Spellerizing—subjecting the heated bloom to the action of rolls having regularly shaped projections on their working surface, then subjecting the bloom while still hot to the action of smooth-faced rolls. The surface working is said to give a dense texture to pipe made from the bloom, adapting it to resist corrosion.

Thomas-Gilchrist process—bessemerizing (q.v.) pig iron high in phosphorus and low in S; in a converter lined with calcined dolomite. The slags formed consist of a basic calcium phosphate which is used for fertilizer.

Thum-Balbach process—a silver-refining process using carbon cathodes, doré anodes and a silver-nitrate nitric-acid electrolyte.

The silver is scraped off the bottom as crystals.

Washoe process—for silver extraction. Consisted in wet crushing and pan amalgamation without previous roasting. Named for the district in which it was first carried on.

Weldon's process for making chlorine—

 $\begin{array}{l} MnO_2 + HCl = MnCl_2 + Cl_2 + H_2O \\ MnCl_2 + Ca(OH)_2 = Mn(OH)_2 + CaCl_2 \\ Mn(OH)_2 + Ca(OH)_2 + O \ (from \ air) = CaMnO_3 + 2H_2O \\ 2Mn(OH)_2 + Ca(OH)_2 + 2O = CaMn_2O_5 + 3H_2O \\ CaMnO_3 + 6HCl = CaCl_2 + MnCl_2 + 3H_2O + Cl_2 \\ CaMn_2O_5 + 10HCl = CaCl_2 + 2MnCl_2 + 5H_2O + 2Cl_2 \end{array}$

Wohlwill process—a process of gold refining, using impure gold bullion as anodes and sheet gold cathodes in a solution carrying 25–30 oz. of gold and 25–30 oz. free HCl (sp. gr. 1.19) per cu. ft. If the anodes contain lead some H₂SO₄ is added. The current density is about 100 amp. per sq. ft., the potential 1 volt. The tanks usually used are porcelain. Platinum and the allied metals remain in the electrolyte, the silver settles out as chloride.

Ziervogel process—this consisted in smelting ore to an argentiferous matte; concentrating the matte to 60 or 70 per cent. Cu; grinding; roasting under such conditions of temperature

control as to decompose the copper sulphate while leaving the silver sulphate undecomposed; leaching out the silver with water, precipitating the silver and recovering it; smelting the residues for copper bottoms from which the gold can be recovered.

Unstable Alloys¹

The following metals do not form stable alloys within the limits mentioned, i.e., if a mixture containing percentages of the materials lying between the critical points is heated, there may be (though not always) an alloy produced at the time, but there will be segregation on standing.

Ten	perature	Zinc-Lead Alloys
650°C.	$\begin{array}{c} \textbf{Between.} & \\ \textbf{Zn} \end{array}$	$\begin{array}{l} = 98.76 \\ = 1.24 \\ = 98.70 \\ = 1.30 \\ \end{array} \text{ and } \begin{cases} Pb = 1.14 \\ Zn = 98.86 \\ Pb = 1.57 \\ Zn = 98.43 \end{cases}$
800°C.	$\mathbf{Between} \left\{ \begin{matrix} \mathbf{Pb} \\ \mathbf{Zn} \end{matrix} \right.$	$= 98.70 \text{ and } \begin{cases} Pb = 1.57 \\ Zn = 98.43 \end{cases}$
	•	Bismuth-Zinc. Alloys
650° C.	$\textbf{Between.} \dots \left\{ \begin{matrix} \textbf{Bi} \\ \textbf{Zn} \end{matrix} \right.$	$= 85.72 \text{ and } \begin{cases} \text{Bi} = 2.32 \\ \text{Zn} = 97.68 \end{cases}$
750°C.	$\textbf{Between} \left\{ \begin{matrix} \textbf{Bi} \\ \textbf{Zn} \end{matrix} \right.$	$= 84.82 \text{ and } $ $\begin{cases} \text{Bi} = 2.47 \\ \text{Zn} = 97.53 \end{cases}$
800°C.	Between $\begin{cases} Bi \\ Zn \end{cases}$	$= 84.17$ and $\begin{cases} Bi = 2.52 \\ Zn = 97.48 \end{cases}$
		Lead-Aluminum Alloys
800°C.		$= 99.93 \text{ and } \begin{cases} Pb = 1.91 \\ Al = 98.09 \end{cases}$
•	T. I.	ismuth-Aluminum Alloys 👑 🥏
800°C.	$\textbf{Between} \left\{ \begin{matrix} \text{Bi} \\ \text{Al} \end{matrix} \right.$	$= 99.72 \text{ and } \begin{cases} \text{Bi} = 2.02 \\ \text{Al} = 97.98 \end{cases}$
	. Ca	dmium-Aluminum Alloys
750°C.	$\textbf{Between.} \dots \left\{ \begin{matrix} \mathbf{Cd} \\ \mathbf{Al} \end{matrix} \right.$	$= 99.78 \text{ and } \begin{cases} Cd = 3.39 \\ Al = 96.61 \end{cases}$

Alloys

Aluminum.—Aluminum containing 0.05 to 0.20 per cent. of Ce is more resistant to corrosion than aluminum itself.

Aluminum alloys for automobile work (Society of Automobile Engineers Specifications 30, 31, 32). Where a light, tough alloy is needed, Al, not under 90 per cent., Cu from 7.0 to 8.5 per cent. Total impurities shall not exceed 1.7 per cent., of which not over 0.2 per cent. shall be zinc. No other impurities are allowable the C, Si, Fe, Zn and Mn. For a mixture possessing strength and closeness of grain that can be cast solid and free from blowholes, Al, not under 80 per cent.; Zn, not over 15 per cent.; Cu, 2-3 per cent.; Mn, not over 0.4 per cent. Total impurities shall not exceed 1.65 per cent., of which not over 0.5 per cent. shall be Si, nor over 1.0 per cent. Fe, nor

¹ROBERT's-Austen, "Introduction to the Study of Metallurgy."

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rulty brane	1.10	36.0		*					 		Melts at 1570°F.
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- Italian	-			8		£					improves the
Britannia medatalar	38			88		8					***********
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AI	Not over 0.3 per cent. Pb. English		Used as a dentidizer, density 8.4,	Melts at 93°C. Practically same as Sterro metal,	the Al.	See Darcet's, Guthrie's, Lipowits's, Lichtenburg's, Newton's, Onion's, Rose's, Wood's Metals.		Melts at 1825°F. With 3 per cent. Pb, melts at	Used for transit frames. Melts at 160°F.
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Monet metal	88 88	8 :	9		: :		60.00	::		Ail 0 05	U. S. Gov't, specifications for castings Tensile strength, 70,000
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Manganese bronse. Newton's metal Needle metal Onion's alloy.	88 64 1.5 84.96 5.3	6.31	0 72	8 70 18 75 7 96 20 00	0.295 31.25 30.00				50.00		Trace of P. Melts about 1600°C. Melts at 94 5°C. Extremely fluid. Melts at 197°F.
Pinchbeck. 83.33 16.76 Part's alloy.	1889 1889		30.0g				63.00	\$ 8		Mo 5.00	A cheap imitation gold Also containe Al, B, and Ma. Said to have tendile attength of 60,000 Ib, per square inch and to remit
Plastic bronse65.00	98.00		:	9.00	6.00 30 00		:	-:			acids.

ALLOYS

Ni Ag Bi Al	14.00 W Sp. gr. 13.6. Coeff. of exp. 0.0000036.	Phosphorita 0.05-0.25 ner cent		24.00 50.00 Melts at 93.75°C.	h. Coeff. of	A.E	80.00 Imitation silver for forks, etc.		Si = Highly resistant to corrosion		2.00 Mn 0.20 Used for propeller castings.	Not so likely to have blow-holes Mn - bronze.	
14			7.10	22:	•	:	17.88	15.00			⊇ ₂ 83 :::	:	15
_		1.65	8	25.00	66.67	:	‡	82.00	: II C		0.10	1.07	none
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3	. 60.00	\$1.80 0.42 0.42 0.42	73.50 20.50 20.50	57.00 97.12	•		13.00 68.52	55.33		86.38 97.80	45.00 48.00	86.77	92.00 49.94 88.94
		Platine. Pewter. Phosnhor bronge	Queen's metal	Rose's metalSheffield German silver	•	Solder, soft for silver	Solder, hard for silver	Sterro's metal	Tantiron	Tombac, English	Solder for German silver Turbadium bronze	Turbine-wheel mixture	Trolley-wheel bronze

over 0.15 per cent. Pb. For a cheap casting not subject to great strains (flat plates, foot-boards, etc.) use Al, 65 per cent.;

Zn, 33 per cent.

Aluminum Alloys for Zeppelin Construction.—Angle brackets, Al, 90.27 per cent.; Zn, 7.8 per cent.; Cu, 0.73 per cent.; traces Fe, Si, Mn, Sn. Channel sections, 88.68 per cent. Al; 9.1 per cent. Zn, other elements as in angle brackets. The braces are evidently simply commercial aluminum.

Aluminum-Silver Alloy.—Argental—silver substitute.

Aluminum-Zinc Alloy.—Macadamum—strong but light cast-Patented alloy, like preceding. Composition unknown. Argental.—Aluminum-silver.

Auer Metal.—35 per cent. Fe and 65 per cent. of the metal obtained by reducing the cerium earths (Misch metal, q.v.).

Bismuth Alloys.—Bi, 3; Pb, 10; Sn, 5. Sticks to glass, melts at 170°C.

Calorized Metal.—See Insuluminum, below.
Cerium Alloys.—The iron-cerium alloys will be found described at length under "pyrophoric alloys." Cerium-platinum alloys have also been recommended for this purpose, while those with zinc and boron, because of the low temperature of the spark are supposed to be especially good for igniting mine The cerium-mercury compounds are exceeding explo-The cerium-iron alloys are apparently definite compounds, CeFe₂, Ce₂Fe₃, Ce₂Fe₅. CeFe₂ is highly oxidizable. Chromax Bronze.—A manganese-bronze in which the man-

ganese is replaced by chromium. It is rather more acid resisting than the manganese-bronze and has a tensile strength even

up to 100,000 lb. per sq. in.

Chromium Alloys.—The chief chromium alloys in commercial use are chromax, nichrome and stellite, which see.

Cobalt-Chromium Alloys.—Stellite.—High tensile strength,

resistant to corrosion, takes high polish.

Cobalt-Chromium-Molybdenum-up to 40 per cent. W and 40 per cent. Mo suitable for high-speed steels.

Cobalt-Chromium-Tungsten.—Harder than stellite.

Cobalt-Tin (40 Co, 60 Sn to 60 Co, 40 Sn).—Very resistant

to acids, but too brittle for ordinary purposes.

Corrosiron.—A silicon-iron made by the Pacific Coast Foundry Co. Shrinkage on casting about % in. per ft. Transverse strength about half that of cast iron. Said to be easily machined and resistant to acids.

Elianite.—A patented composition; withstands acids and

halogens; melts at 1250°C. Probably a ferro-silicon.

Ferro-alloys.—The following brief description of the ferroalloys chiefly used is condensed from The Mining Journal, Feb. 20, 1915. These alloys may be grouped in two divisions, those used as alloying materials and those used as deoxidizers.

Ferro-manganese.—The alloy is chiefly used as an 80 per cent. ingredient, and is employed in the Thomas, Martin, and electro-steel furnaces. The addition varies from 0.5 to 1.5 per cent. of the weight of the steel. This product is produced

at present almost exclusively in the ordinary mass furnaces, and so far as ferro-manganese is concerned, the electric smelter has not hitherto been able to compete, the reason being simply that manganese is a comparatively easily smelted metal, and with the high temperature to be looked for in the electric furnace the metal would be apt to get overheated, with the risk of volatilization. In applying ferro-manganese, unlike ferrosilicon, it is heated and added to the steel bath, preferably in a molten condition. Apart from its deoxidizing effect, ferromanganese serves directly to increase the toughness of the iron to a considerable degree. As silicon and manganese together combine in a direct deoxidizing and toughening effect, they are often required to be delivered in the following combinationsnamely: Ferro-silicon-of about 25 per cent. Si content is usually added in the proportion of 0.3-1 per cent. of the body of the steel to be treated. It has a quieting effect and is usually placed in the converter in the quantity desired. Ferro-manganese-silicon—in various content percentages. The usual association for this product is about 70 per cent. manganese and silicon. Silicon-aluminum—(usually per cent. known in commerce as "Sical") is produced with about 52 per cent. Si and about 27 per cent. Al. Calcium-silicidehas usually about 27 per cent. Ca and about 64 per cent. Si. Calcium-Silicon-Aluminum.—All these last associations (ferrosilicon-aluminum, calcium-silicide, manganese-silicon, calcium-silicon-aluminum) are employed in the Martin and electro-steel works. The quantity added is around 1 per cent. of the steel bath's weight. The above percentages of the several metals are the values usually delivered, though there are a number of variations, and the several steel works often use their own prescriptions for these combinations. Ferro-Chrome.— The above alloy was formerly produced entirely in mass furnaces (where, indeed, it is to a certain extent produced at the present time). Owing to similar conditions to those stated above in reference to the mass furnace's connection with the ferro-silicon industry, one must here content oneself with a lower product percentage with a relatively high carbon content. Lately the demand for a high per cent. alloy is specially referable to ferro-chrome, from which one may practically take it for granted that the greater part of the ferro-chrome at present employed in the steel industry is produced in electric smelters. The article is delivered, according to the requirements of the steel works, with various carbon contents, from 1/2 per cent. up to 10 per cent. C., and around 65 per cent. Cr. Ferrochrome is employed as an addition to iron in Martin, electrosteel, and crucible furnaces to increase the hardness of the iron. The addition is up to 6 per cent. of the weight of the steel under Ferro-wolfram—is added to the steel bath in quantities up to 24 per cent., and increases the cutting capacity of the steel. Ferro-molybdenum—operates in the same manner as wolfram, though added in lesser quantities. The maximum addition is about 2 per cent. It is used for special shop tools.

Ferro-cobalt—has also recently been employed as an added ingredient in the manufacture of steel shop tools. The addition ranges up to about 4 per cent. Ferro-vanadium.—Besides operating as a deoxidizing medium this alloy has a direct effect on the steel bath, in that it to an unusually high degree increases the toughness of the steel. It is employed in the Martin furnace up to 0.2 per cent., and in electro and crucible furnaces up to 2 per cent. Ferro-titanium—has lately been entirely employed as a deoxidizing medium, especially in America in Martin furnaces, and in England in crucible furnaces. Ferrovanadium—is used in electric and crucible furnaces. above-named alloys the main consumption is, of course, confined to ferro-silicon and ferro-manganese. The European consumption of high per cent. ferro-silicon is at present about 35,000 tons and of ferro-manganese about 80,000 tons yearly. As regards the second group—ferro-alloys as a pure deoxidizing medium—we have a number of combinations, of which the most important are ferro-nickel, ferro-chrome, ferro-wolfram, ferro-molybdenum, ferro-cobalt, ferro-vanadium, ferro-manganese, and ferro-silicon. Ferro-Nickel,—Pure nickel is used to a large extent as an addition to the steel bath. Lately, however, there have been requests from the steel works that this nickel be added to the steel bath in the form of ferronickel. As a chief reason for this, it may be mentioned that nickel in the large steel works is often liable to be stolen. therefore, the nickel is previously combined with a certain quantity of iron, the metal will be of no value to other than just that particular steel works, and thus robbery is obviated. Another and quite a general advantage in the use of nickel in the form of ferro-nickel is that nickel before it is added to the steel bath is previously associated with iron. By this one gets a comparatively large quantity for the bath, and the metallic nickel is thereby more evenly distributed. Ferro-nickel is supplied at present with about 30 per cent. Ni, and is used in Martin and electro-steel furnaces. The addition can go right up to about 35 per cent. of the steel's weight. description of these deoxidizes would be repetition.

High-speed Steel.—C, 0.45-0.85 per cent.; Si, tr.-0.20 per cent.; Mn, 0.10-0.50 per cent.; W, 8 to 18 per cent.; Cr, 2.50-6.5 per cent.; Mo, 0-2.50 per cent.; V, 0-1.5 per cent.; Co, 0-5

per cent.

High-speed Steel (Beth. Steel Co., Paris Exposition).—C 0.6 per cent.; Mn, 0.2 per cent.; Si, 0.1 per cent.; Cr, 4 per cent.

W, 18 per cent.

Hydraulic Bronzes.—The presence of very small proportion of aluminum makes castings porous throughout, although the look solid. Iron and antimony are also detrimental. cocks, pistons, bushings, etc., S. D. Sleeth recommends Ca 72.50 per cent.; Sn, 1.75 per cent.; Zn, 19.25 per cent.; Ph 6.50 per cent, for alloys for high pressures, 3000 lb. per s (See the general table, p. 500.)

Insuluminum.—The name of a metal patented by the General

Electric Co. It consists of steel given a surface impregnation of aluminum. When exposed to air or gases containing oxygen, the surface oxidizes to alumina. The resulting composition will resist for an indefinite time the continued action of oxygenbearing gases at 1000°C.

Ivanium.—A patented aluminum alloy (British). Melts at

about 300°C.

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Japanese Bronze (Kalischer's analyses).—Copper, 75.53 to 76.64 per cent.; lead, 11.88 to 12.2 per cent.; zinc, 6.53 to 6.58 per cent.; tin, 4.48 to 4.36 per cent.; iron, 0.47 to to 0.33 per cent.

Kaiserzinn.—Practically britannia, which see in alloys.

Kunheim Metal.—A pyrophoric alloy containing hydrides of the cerium earth metals with magnesium and aluminum,

Macadamum.—An aluminum-zmc alloy.

Manganese Bronze.—Copper, 60; zinc, 40 with iron in small and manganese in varying quantities (S.A.E. Spec. No. 29). Should test about 60,000 lb. per sq. in. tensile strength; yield point about 30,000 lb. per sq. in.; elongation in 2 in., 20 per cent.

Misch Metal.—Cerium, 42 per cent.; lanthanum, didymium,

etc., 57 per cent. (These figures are approximate only.)

Mushet Steel.—C, 2 per cent.; Mn, 1.75 per cent.; Si, 0.75 per

cent.; Cr, 0.4 per cent.; W, 5.5 per cent.

Nickel and Cobalt.—The use of zirconium for hardening nickel or cobalt has been patented. Nickel with 8 to 10 per cent. of zirconium is claimed to take a fine cutting edge; either nickel or cobalt with 8 to 15 per cent. of zirconium has its melting-point reduced below that of any one of the three separate metals, with an increase of electrical resistance; and with 16 to 30 per cent. of zirconium the hardness is greatly increased, giving an alloy suitable for cutting tools. Some nickel-cobalt alloys resistant to acids are described just below, under noncorrosive alloys.

Non-corrosive Alloys.—It has been known for some time that cobalt-tin alloys containing about equal percentages (from 40 to 60) of the two metals are practically acid proof, withstanding even aqua regia, but the alloys are too brittle for practical use. According to Robert Grimshaw (Chemical Engineer, February, 1913) copper alloyed with from 5 to 20 per cent. of this CO-Sn alloy can be readily machined and still retains a high degree of non-corrodibility. The alloys are best prepared by dissolving the CO-Sn alloy in the copper. An alloy of Ni and Cu in equal proportions is highly resistant to hot, concentrated sulphuric Even more resistant are the alloys prepared by adding copper to molten nickel-tungsten. The resistance normally increases with the percentage of tungsten, but specially resistant are: Ni, 78 per cent.; Cu, 20 per cent.; W, 2 per cent.; Ni, 70 per cent.; Cu, 25 per cent.; W, 5 per cent.; and Ni, 75 per cent.; Cu, 15 per cent.; and W, 10 per cent. These alloys are said to roll well. Electric resistance is high. Another still more resistant alloy is obtained by adding ferro-tungsten to cupronickel to give Ni, 52 per cent.; Cu, 40 per cent.; Fe, 4 per cent.; W, 4

per cent.

The silicon-iron alloys are resistant to both sulphuric and nitric acid. These alloys are marketed under the names tantiron, ironac and elianite in England, duriron, tantiron and corrosiron in the United States. Duriron has approximately the following composition: Si, 14-14.5 per cent.; Mn, 0.25-0.35 per cent.; total carbon, 0.2-0.6 per cent.; P, 0.16-0.20 per cent.; S under 0.05 per cent. It melts at 2500-2550°F., has a specific gravity of about 7, a compression strength of about 70,000 lb. per sq. in., tensile strength about 12,000-14,000 lb., and a coefficient of expansion of about 0.00001565 per deg. F., conductivity about 2.5 per cent. that of standard annealed copper.

An approximate analysis of tantiron is as follows: Si, 14-15 per cent.; S, 0.05-0.15 per cent.; P, 0.05-0.10 per cent.; Mn, 2-2.5 per cent.; C (graphite), 0.75-1.25 per cent.; melts at about 2550°F.; sp. gr., 6.8; and tensile strength about 6-7 tons

per sq. in.

Phonoelectric Wire.—See silicon-bronze in preceding table.
Pyrophoric Alloys.—There are in general cerium alloys.

T commonest is ferro-cerium, containing about 15 per cent. Fe, 2 per cent. of Bi or Sb to harden it, 5 per cent. of copper to make it more fusible; and silicon, a general impurity of the rare earth metals, taken up from the clay crucibles in which the metal is The most highly pyrophoric alloy is probably 1 part platinum with 3 parts of cerium. The most highly pyrophoric of the iron alloys is probably reached at about 70 per cent. of Ce. The alloys with 25 The alloy is hardest at 60 per cent. Ce. per cent. of magnesium or aluminum are brittle and easily pulverized. The presence of carbides is undesirable, as the alloys, unless kept under oil, oxidize and lose their efficiency. The raw materials for these alloys is the waste from the factories which extract thorium from monazite sand. The residues of the various rare earths are converted into chlorides and the anhydrous salts are electrolyzed in clay or in water-jacketed iron crucibles provided with iron cathodes. The fluorides are not convenient for reduction. (See Misch Metal, p. 505.)

Shakado.—A Chinese "art bronze," really a cupro-gold alloy. Shibuichi.—A Chinese "art bronze," really a cupro-silver

allov.

"Stainless" steel—used chiefly for cutlery. A typical analysis is said to be: Fe, 86.6 per cent.; Cr, 12.7 per cent.; Co, 0.45 per cent.; C, 0.28 per cent.; Si, 0.01 per cent.; Mn, 0.12 Resists tarnishing in contact with food stuffs.

Stellite.—A white non-corrosive extremely hard metal patented by Elwood Haynes. It consists of 10-25 per cent. Cr, 90-75 per cent. Co and may carry a little tungsten or

molybdenum.

Talmi Gold.—86.4 per cent. Cu; 12.2 per cent. Zn. A Mosaic

gold.

Ulcoloy.—A copper-lead alloy containing comparatively large quantities of copper held uniformly distributed through

Where found	٥	Mn	86	82	Δ,	Cu	z	Ten-	Analyzie
	Per cent	Per cent.	Per cent. Per	Per cent.	Per cent.	Per cent. Per cent.	Per cent.		
Hartlepool	9	Ö		0.062				:	Wilson
Α,	0 20	080	0.35	0.027	0.043				Pattieon and Stead
ğţ	0.670	0.515	0.336	0.037	0.048	0 083	•		Pattison and Stead
West Hartlepool 4	0 870	1001	0.252	0.087	0 028	080	:	3	Pattison and Stead
	\$ \$ \$	100	4.024	0.000	9.0	0.000	:	_	Pattison and Stead
		0.000	200.0	0.00	0.00	,	•	:	F. Canter
West Hartlehool	765	0.455	344	0.0	900				F. Saniter
	0.630	0.550	0.400	0.043	0.077				F Saniter
West Hartlepool (8 in. ab) .10	0.86	1.03	0.186	0 053	0.045		:	:	F. Saniter
West Hartlepool	1.12	2.00	0 23	0.054	0.038	::		:	Bainbridge
Whitby and Swarborough 12	0.850	1.330		0.080	0.106				
Lord and Scarborough 13	0.60	1.21	0.334	0.071	0.069		0.0112	3	Pattison and Stead
Whithy and Scarbarough It	0.74	170	0.261	4.00	0.064	:	:	62	Pattison and Stead
Dunkirk	200	2001	0.00		200	:	:	:	Bainbridge Dettings and Read
Manders	88	1 05	1	000	0.086				Wilson and Bainbridge
Flanders	0 93	96.0		0.059	0.065				Wilson and Bainbridge
Flanders 19	0.74	0 98		0.054	0.050		:		Wilson and Bainbridge
Germen 20	0.393	1.400	0.210	0.035	0.041		•	:	Billeta
France21	200	0.870	107		0.048			:	Sillare

1 Ni, 3.1 per cent.; Cr. 3.351 per cent.; Fe (by difference), 91.862 per cent.

the mass during the cooling period. It is sold by the United Lead Co. chiefly as a metallic packing and for acid-proof valves

and pumps.

Shell Steel.—The general conditions for proper shell steel were laid down by Dr. J. E. Stead in a lecture given before the Cleveland Institute of Engineers (The Engineer, Jan. 14, 1916). These are: (1) There must not be such porosity of the base of the shell as to admit the hot propellant gas in on the exploding charge inside the shell. (2) The steel must not be too soft, for if it is, the shell bulges in the gun, causing excessive friction in the barrel. This may lead to the accentuated pressure from the propellant gases exceeding the bursting pressure. (3) The steel must not be too brittle. It should also break so that the fragments may have sharp points and edges, called by Doctor Stead "shear-fractured surfaces." The analysis of many German shells shows that that country allows a very wide range for its shells, as follows:

Carbon	0.393 to 1.12	per cent.
Manganese		
Silicon	0.078 to 0.597	per cent.
Sulphur		
Phosphorus		

From the analyses of these German steels it appears that British makers have been insisting on a freedom from phosphorus that is totally unnecessary. From the analyses of German shell steel it is judged that basic bessemer steel is being used. This is argued from the nitrogen present, showing that open-hearth steel is not necessary.

The analyses of German shells are given on page 507.

Cast Projectiles

In the issue of May 27, 1916, of Le Génie Civil is given an illustrated description of the manufacture of cast projectiles; these are of cast iron, the greater part now made being, however, of cast iron with an admixture of steel, the two melted down together. Our contemporary adds that cast iron projectiles have very frequently been used for the sake of cheapness in firing practice at sea. Cast projectiles are manufactured in large quantities and for all caliber guns. Machining is generally the same as in the case of forged-steel projectiles; in some cases, however, in that of 90-mm. projectiles, for example, the base, band seating and shoulder alone are machined, the cylindrical part and ogival head frequently being left rough cast. The specification of July 31, 1915, gives some indications concerning the quality required for the cast iron. The mechanical tests are carried out with test-pieces 200 mm. in length, 40 mm. square; these test-pieces are placed on knife-edge bearings 150 mm. apart and are subjected to a falling weight of 12 kg., the average height of fall of which has to be at least 450 mm. Tensile tests are made on specimens 150 mm. long, cast at a diameter of 18 mm. and turned down to 16 mm.; these have

to withstand a tensile stress of 25 kg. per square mm. When machined, the shells have to withstand during 10 seconds a water-tight test at a pressure of 300 kg. per square cm. when the caliber is equal to or below 160 mm. and a pressure of 200 kg. per sq. cm. for the larger calibers. The new specification does not define the analysis of the cast iron. An appendix to a former specification dated November 1, 1914, gave, simply as an indication, the following figures:

Silicon 1.25 to 1.50 per cent.

Manganese 0.50 to 0.70 per cent.

Sulphur 0.07 per cent.

Phosphorus 0.07 per cent.

The percentage of carbon was not stated. The artillery qualities AM or BM of pig-iron were recommended; these have the following analyses:

	Silicon, per cent.	Manganese, per cent.	Phosphorus, less than per cent.	Sulphur, less than per cent.
AM pig-iron	1.75 to 3	1.50	0.09	0.05
BM pig-iron		1.10	0.09	0.005

In case these grades were not available, the grades A or B were to be taken, with an addition of 15 to 18 per cent. of steel; the coke consumption for the heat in the cupola furnace being from 15 to 18 per cent., with a pressure of blast equal to a water column of about 18¾ in. The above figures can, however, be varied within somewhat wide limits and the results be satisfactory. The percentage of silicon in the final product can also vary somewhat largely, provided the proportion of manganese follows in like progression. The cast iron may have any of the following compositions, all of which give results equally satisfactory:

•	Per cent.	Per cent.	Per cent.
Silicon	1.50	2.20	1.40
Manganese	0.44	0.98	0.70
Phosphorus	0.174	0.10	0.09
Sulphur	0.095	0.07	0.06

The "steely cast iron" now largely used is obtained in various ways, directly or by mixture, in the open-hearth furnace, the converter, the electric furnace, or the cupola. The melting in the cupola is the simplest process, and the one most followed. The charge consists of a mixture of pig-iron high in silicon, about 2.5 per cent., the manganese being between 0.8 and 1.25 per cent., to which an addition of from 30 to 40 per cent. of steel is made, unless high-class hematite pig is available, which allows a reduction in the proportion of steel added. The loss of silicon in the melting process, which has to be taken into account, is 0.2 to 0.3 per cent. Projectiles cast of steel alone would not have sufficiently smooth and sound surfaces. Cast iron alone is not suitable for shells containing a high explosive charge, while cast iron with an admixture of steel solves the difficulty and yields shells having a sufficiently low dead weight.

In these latter, the wall thickness is greater than that of wrought-steel shells, but the shells of "steely cast iron" contain a sufficiently large high explosive charge to produce remarkable effects.

The French chemical specifications for shell steel are said to be: Carbon minimum, 0.30 per cent.; Si, 0.15-0.25 per cent.; Mn, 0.50-0.80 per cent.; P, 0.03-0.08 per cent.; S, maximum,

0.05 per cent.

Alloys having remarkable properties at very high or very low temperatures.—L. Guillet. Rev. metal. 11, I, 969-70 (1914).—Alloys or metals having a high temperature resistance have a breaking strength and an elastic limit of 5-8 kg. per sq. mm. at about 750-800°. A Ni-steel alloy hardened with Cr and W is described which has a breaking strength of 24 kg. at 800°. Another alloy shows a resistance of 50 kg. at -195°, while soft steel gives a resistance of no more than 3 kg. at this temperature. Tammann cites two alloys of Cr-Co, one of which (Cr 25 per cent., Co 75 per cent.) has a resistance of 44.9 kg. at 720°; the other (Cr 30 per cent., Co 70 per cent.) has a resistance of 65.1 kg. at the same temperature.

Allotropy of Metals

In the preface to the first edition of this book I made mention that in its preparation I had often been puzzled by the fact that the various constants of the elements as determined by apparently equally reliable workers were hopelessly at variance. Some researches of Professor Cohen at the Van't Hoff Laboratory seem to give the answer to this seeming discrepancy.

To take a specific instance, dilatometric observations on the metal showed a sudden change at 75°C. The metal below 75° (the α modification) has a specific gravity of 9.732, the metal above (β modification) 9.712. Although the transition point is well defined, quick cooling or quick heating permits the α and β modifications to exist in the same mass.

Antimony also has strongly marked α and β modifications, the transition point being about 96°C. The transformation

temperature of copper is about 70.5°C.

The explanation, then, of the question of widely varying constants, is apparently that α and β modifications exist in most of the metals and that accompanying a determination of the constants should be a statement of the relative proportion of α and β modifications. As it appears to be true that at temperatures below the critical temperature the change from β to α may be extremely slow, we might determine, say, the coefficient of linear expansion of bismuth each month for 6 months and get a different result each time, as what was originally a large amount of β modification changed slowly over to α .

It does not appear, either, that it may not be found later that γ and even δ modifications of some of the elements may not

be found.

Fluxes for Soldering and Welding¹

Iron or steel. Tinned iron.

Copper and brass.

Zinc. Lead.

Lead and tin pipes.

Aluminum.

Borax or sal-ammoniac. Resin or tin chloride.

Sal-ammoniac or zinc chloride.

Zinc chloride. Tallow or resin.

Resin and sweet oil.

Borax 96 parts, sodium bisulphate 4 parts.²

<sup>MEGRAW, "Practical Data for the Cyanide Plant."
Given as a Danish flux by Brass World, May, 1915. Seems very question</sup>able whether it will work.

Some General Considerations Regarding Alloys

A pure metal is always softer than its alloys; it is usually more malleable and ductile; the expansion of alloys by heat cannot be calculated from the coefficients of expansion of the constituents; the specific heat of alloys at temperatures considerably removed from the melting points is the mean of the specific heat of the metals composing them; alloys never conduct heat as well as the components; the electric conductivity is also usually lower than that of either constituent.

SHEET-ZINC GAGE

	Ameri	ican	Belgi	an	Vieille Mo	ntagne
Gage number	Thickness, decimals of an inch	Weight per sq. ft., lb.	Thickness, decimals of an inch	Weight per sq. ft., lb.	Thickness, decimals of an inch	Weight per sq. ft., lb.
1	0.002	0.075	0.0018	0.068	0.004	0.150
2 3	0.004	0.150	0.0036	0.135	0.006	0.225
3	0.006	0.225	0.0055	0.206	0.007	0.263
4 5	0.008	0.300	0.0073	0.274	0.008	0.300
Ð	0.010	0.375	0.0091	0.341	0.010	0.375
6	0.012	0.450	0.0110	0.413	0.011	0.413
6 7	0.014	0.525	0.0128	0.480	0.013	0.488
8	0.016	0.600	0.0146	0.548	0.015	0.563
9	0.018	0.675	0.0165	0.619	0.018	0.675
10	0.020	0.750	0.0180	0.675	0.020	0.750
11	0.024	0.900	0.0217	0.814	0.023	0.863
12	0.028	1.050	0.0254	0.953	0.026	0.975
13	0.032	1.200	0.0290	1.088	0.029	1.088
14	0.036	1.350	0.0326	1.223	0.032	1.200
15	0.040	1.500	0.0364	1.365	0.038	1.425
16	0.045	1.688	0.0400	1.500	0.043	1.613
17	0.050	1.875	0.0437	1.639	0.048	1.800
18	0.055	2.063	0.0478	1.793	0.053	1.988
19	0.060	2.250	0.0509	1.909	0.058	2.175
20	0.070	2.625	0.0581	2.179	0.063	2.363
21	0.080	3:000	0.0728	2.730	0.070	2.625
22	0.090	3.375	0.0764	2.865	0.077	2.888
23	0.100	3.750	0.0800	3.000	0.084	3.150
24	0.125	4.688	0.0896	3.360	0.091	3.413
25	0.250	9.375	0.0992	3.720	0.098	3.675
26	0.375	14.063	0.1088	4.080	0.105	3.938
27	0.500	18.750	1	1	1	1
28	1.000	37.500		1	1	1

WIRE AND SHEET METAL GAGES COMPARED²

-								
	ning- a or s'iron gage,	American or Brown & Sharpe's gage, inch	Roebling's and Wash- burn & Moen's gage, inch	gage,	Sritish mperial andard ire gage, inch	Legal standard since Mar. 1, 1884, mm.	भूरुव	1
Number of gage	Birming-ham or stubs' iro gage inch	American or Brown & Sharpe's	Roebling's and Wash burn & Moen's gage, inch	ا لَوْ يَدُ ا	British Imperisl Standard wire gage	Legal standard since Mar 1, 1884, mm.	U.S.sheet and plate gage, inch	Number of gage
43.5		.E.Y 2	Soeblin and Wa burn Moen'	b's s fe ga inch	British Imperiu itandar rire ga	Legal sudar ce M 188 mm.	- 선명·표	出る
	5 8 9 9 B	S. 4	유그 부승 한	P.o.c.	でいる。	S A S L B		
N of	Birmi ham Stubs' wire g	보고있다	Roel snd bud Mage	Stub'avire	Brit Imp Stan Wire	L ta ta L	J. S. s and p	24
	H _ 20 ₹	A PAS		Stub's wire g	∟∞ ≽	8.18		-
		}						1
0000000			0.49		0.500	12.7	0.500	76
000000			0.46		0.464	11.78	0.469	96
00000			0.43		0.432	10.97	0.438	56
0000	0.454	0.46	0.393	l	0.400	10.16	0.406	36
000	0.425	0.40964	0.362	l	0.372	9.45	0.375	36
00	0.380	0.3648	0.331	[0.348	8.84	0.344	36 36
Ŏ	0.340	0.32486	0.307		0.324	8.23	0.313	ĺň
ĭ	0.300	0.2893	0.283	0.227	0.300	7.62	0.281	0
2		0.25763	0.268	0.219	0.276	7.01	0.266	3
3	0.259	0.22942	0.244	0.212	0.252	6.40	0.250	8
Ă	0.238	0.20431	0.225	0.207	0.232	5.89	0.234	4
Š	0.220	0.18194	0.207	0.204	0.212	5.38	0.219	Ē
ő	0.203	0.16202	0.192	0.201	0.192	4.88	0.203	6
7	0.203	0.14428	0.192		0.192	4.47	0.188	7
8	0.165	0.12849	0,1//	0.199		7.7/ 4 ne	0.108	
9			0.162	0.197	0.160	4.06		8
40	0.148	0.11443	0.148	0.194	0.144	3.66	0.156	
10 11 12	0.134	0.10189	0.135	0.191	0.128	3.25	0.141	10
TI	0.120	0.09074	0.120	0.188	0.116	2.95	0.125	11.
12	0.109	0.08081	0.105	0.185	0.104	2.64	0:109	12
13 14	0.095	0.07196	0.092	0.182	0.092	2.34	0.094	13
12	0.083	0.06408	0.080	0.180	0.080	2.03	0.078	14
15 16	0.072	0.05707	0.072	0.178	0.072	1.83	0.070	15
16	0.065	0.05082	0.063	0.175	0.064	1.63	0.0625	16
17	0.058	0.04526	0.054	0.172	0.056	1.42	0.0563	17
18	0.049	0.04030	0.047	0.168	0.048	1.22	0.0500	18
19	0.042	0.03589	0.041	0.164	0.040	1.02	0.0438	19
20	0.035	0.03196	0.035	0.161	0.036	0.91	0.0375	20
21 22		0.02846	0.032	0.157	0.032	0.81	0.0344	21
22		0.02535	0.028	0.155	0.028	0.71	0.0313	22
23	0.020	0.02257	0.025	0.153	0.024	0.61	0.0281	23
24		0.02010	0.023	0.151	0.022	0.56	0.0250	24
25		0.01790	0.020	0.148	0.020	0.51	0.0219	25
26		0.01594	0.018	0.146	0.018	0.46	0.0188	26
27		0.01419	0.017	0.143	0.0164	0.42	0.0172	27
. 28.		0.01264	0.016	0.139	0.0148	0.38	0,0156	28
29		0.01126	0.015	0.134	0.0136	0.35	0.0141	29
3 0		0.01002	0.014	0.127	0.0124	0.31	0.0125	30
81		0.00893	0.013	0.120	0.0116	0.29	Q.0109	31
8 2		0.00795	0.013	0.115	0.0108	0.27	0:0101	32
. 33.		0.00708	0:011	0.112	0.0100	0.25	0:0094	33
34		0.00630	0.010	0.110	0.0092	0.23	0.0086	34
85		0.00561	0.0095	0.108	0.0084	0.21	0.0078	35
36		0.00500	0.0090	0.106	0.0076	0.19	0.0070	36
37		0.00445	0.0085	0.103	0.0068	0.17	0.0066	37
38		0.00396	0.080	0.101	0.0060	0.15	0.0063	38
		0.00353	0.0075	0.099	0.0052	0.13	•••••	39
40		0.00314	0.007	0.097	0.0048	0.12	• • • • • •	40
41	 	.		0.095	0.0044	0.11	• • • • •	41
42		. <i></i>		0.092	0.0040	0.10	• • • • • •	42
43				0.088	0.0036	0.09		43
44	<i></i>			0.085	0.0032	0.08	• • • • • •	44
				0.081	0.0028	0.07		45
			•	0.079	0.0024	0.06		46
47		1 -]	0.077	0.0020	0.05		47
48			,:	0.075	0.0016	0.04		· 48
				0.072	0.0012	0.03		49
50	• • • • • • • • • • • • • • • • • • • •	[0.069	0.0010	0.025	• • • • • •	50
	<u> </u>	44.7.6.1	1 17		T. 1 . T.	1 11 041	TD 1145	'

¹ From Kent's "Mechanical Engineer's Pocket Book," 8th Edition, p. 30; and "American Machinist," p. 931, Dec. 5, 1912. The moral of the above table is to specify wire by mils and not by gages.

33'

IMPURITIES IN COMMERCIAL METALS

Aluminum: Fe, 0.18 per cent.; Si, 0.17; Na, 0.05; Cu, tr. Electrolytic aluminum will carry 98.52 to 99.34 per cent. Al, and Si from 0.07 to 1.14 per cent. according to RICHARDS.

Analyses of Aluminum (By W. H. WITHEY, Nat. Phys. Lab.)

·	A	В	C	D
Copper Iron Zinc Silicon Silica Nitrogen Sodium Sulphur Phosphorus	0.1829 0.0060 trace 0.333 0.040 trace nil	0.0800 0.4077 0.0120 0.2320 0.340 0.006 trace nil nil	0.0463 0.1972 0.0075 trace 0.290 0.042 trace nil nil	trace 0.1522 0.0024 trace 0.459 0.092 trace nil nil

CHEMICAL ANALYSES OF REFINED COPPER¹

Element	Lake	Lake	Electro-	Best
	wire	arsenical	lytic wire	selected
	bar	ingot	bar	English
Cu + Ag Cu Ag Pb Bi As Sb Se + Te Fe Ni Zu S O (by diff.) Sn Conductivity, annealed Conductivity, hard drawn Difference due to hard drawing Tensile strength, lb. per sq. in Twists in 6 in Elongation, per cent Bends, annealed	99.900 99.890 0.0096 (2.8 oz.) 2.0031 0.0000 0.0062 0.0000 0.0020 0.0028 0.0090 0.0016 0.0753 96.49 93.84 2.65 67.590 17 1.032 11.0 0.080	(7.41 os.) 0.0027 0.0000 0.3183 0.0000 N. d. 0.0056 0.0153 0.0000 0.0071	99.9548 99.953 0.0018 (0.56 os.) 0.0010 0.0000 0.0000 0.0026 0.0038 0.0028 0.0028 0.0026 0.0315 	99.5510 99.530 0.021 (7.02 os.) 0.1331 0.0000 0.0071 0.0087 0.0066 0.0044 0.1112 0.0000 0.0074 0.1705

¹ HOFMAN, "Metallurgy of Copper," p. 12.
2 In 8 in.
3 In 60 in.

Antimony: Cookson's: Pb, 0.041; Sn, 0.035; As, tr.; Cu, 0.04; Fe, 0.010; Zn, tr. Cookson's: Pb, 0.102, Sn, tr.; As, 0.092; Bi, none; Cu, 0.046; Cd, none; Fe, 0.004; Zn, 0.034; Ni and Co. 0.028; S, 0.086; Sb (by difference), 99.608. HALLETT's: Pb, 0.669; Sn, 0.175; As, tr.; Cu, 0.038; Fe, 0.014; Zn, tr. HALLETT's: Pb, 0.718; Sn, 0.012; As, 0.021; Bi, none; Cu, 0.046; Cd, none; Fe, 0.007; Zn, 0.023; Ni and Co, none; S, 0.128; Sb (by difference), 98.856. Japanese: Pb, 0.443; Sn, 0.175; As, 0.008; Cu, 0.034; Fe, 0.015; Zn, tr. Japanese: Pb, 0.424; Sn, 0.012; As, 0.095; Bi, none; Cu, 0.043; Cd, none; Fe, 0.007; Zn, 0.023; Ni and Co, none; S, 0.201; Sb, 99.195. Chinese: Pb, 0.018, Sn, 0.035; As, 0.017, Cu, 0.008; Fe, 0.007; Zn, tr. Chinese: Pb, 0.029; Sn, none; As, 0.090; Cd, none; Fe, 0.004; Zn, 0.027; Ni and Co, tr.; S, 0.078; Sb, 99.760.

Bismuth (American): Pb, Au, Cu, Sb, Te, traces; Ag, 1.37

oz. per ton; Fe, 0.009 per cent.

Copper (electrolytic): Cu, 99.89; Bi, none; Ni, 0.0100; As, 0.00108; Sb, 0.00515 per cent.; Ag, 0.96 oz. per ton. presence of a small amount of oxygen, less than 0.06 per cent., seems to affect the copper beneficially, and in most of the electrolytic copper, which carries from 99.89 to 99.94 per cent. Cu, oxygen forms by far the largest part of the balance.2

Iron, pure, is defined by the American Society for Testing Materials (Atlantic City meeting, 1915) as containing under 0.02 per cent. C; 0.03 per cent. Mn; 0.03 per cent. S; 0.01 per

cent. P; 0.03 per cent. Cu.

Lead (electrolytic): Ag, 0.29 oz. per ton; Bi, 0.0024 per cent.;

Cu, 0.0010; As, tr.; Sb, 0.0066; Fe, 0.0028.

Lead (PARKES process), American: Bi, 0.066-0.110; Sb, 0.0028-0.0076; As, 0.00025-0.009 per cent.³

Nickel: Ni, 99.8+; Fe, 0.04; Si, 0.01.

Tin.—(Pulo Brani, 1892, after Henry Louis): Sn, 99.76; Sb, 0.07; Pb, 0.02; Fe, 0.14 per cent.; Cu, As, none. English: Sn, 99.73; Fe, 0.13; Pb, —; Cu, tr. The presence of over 0.8 per cent. of copper spoils tin for tin-pot work, according to my own experience, yet Louis gives as a typical English tin analysis:

Sn, 98.61; Fe, tr; Pb, 0.20; Cu, 1.16 per cent.

Zinc.—The impurities found in zinc may amount to 2 per cent. of its weight. They are: Pb, Fe, Cd, Cu, C, Si, As, Sb, S, Sn, Ag, Tl, In and Ga. Tin has been found in New Jersey metal. A moderate tenor in Pb makes zinc ductile and malleable, but over 1.5 per cent. Pb renders it tender. Zinc for the brass trade should not carry over 0.05 per cent. Fe. Cd is objectionable if the zinc is to be used for zinc white. Copper and tin

³ See also p. 568.

¹ Min. and Sci. Press, July 10, 1915.

² See also pp. 581 and 583.

516 METALLURGISTS AND CHEMISTS' HANDBO

both render the zinc hard and brittle. Arsenic renders spelter brittle and hard to melt. It is also objectionable in zinc which is to be used for generating hydrogen or in cyanide precipitation, owing to the danger of poisoning workmen with arseniuretted hydrogen.

Roasting
DETAILS OF MONTANA ROASTING-FURNACES

DETAILS OF	11101	41244		, 414. F. F	110-4	OPHAR		
•	Tons rossted in 24 hr.	Horsepower	% sulphur in concentrates	% sulphur in	Area of hearths,	Concentrates per sq. ft. of bearth, ib.	Lb. of coal per ton of con- centrates	Cost of rossting per ton
Hand reverberatory, 69½ ft. × 16 ft	13		35	7-B	1112	111	307.0	82.00
Alien-O'Hara, two hearths, 94 ft. 0 × 9 ft.	51	3 64	35	8	1692	77	145.0	0 78
Brückner cylinder, 8 ft. × 16 ft	18- 20	1 5	87	9.5			540.01	A 25
Pearce, single deck	142	1 5	M	7-8	505	55	400.0	0.981
Pearce, double deck, 6-ft.	301	8 0	шь	6-7	1010	59	400.0	0.982
Pearce, double deck, 7-ft.	421	3.0	35	6–7	1218	69	182.0	0.981
Keller-Galord-Cole, two sets of six hearths	50	134	38	7-10	****	88	67.0	
Wethey, two sets of four hearths, 50 ft. × 5 ft.	60	4 0	40	8	2000	60	110.0	
Wethey, two sets of four hearths, 65 ft. × 10 ft.	90	4 0	35	5-6	2600	70	80 O	
Herreshoff, five hearths	5-6		35	6	135	80		0.40
MacDougall-Evans- Klepetko, six hearths	40	1 667	35	7	952	84	,	0 35
Pearce multiple, six hearths	56*	12	35	6-7	2947	38	28 5	0 881

Lead Ores.—It may safely be said that there is no apparatus able to compete with the DWIGHT-LLOYD and HUNTINGTON-HEBERLEIN installations in dead-roasting lead ores. Consequently, discussion of the older types, the BRUCKNER cylinders,

Data obtained from operations of six months at Great Falls.

Average.

These low figures are due to the character of the ore (Gagnon Mine) which carries from 8 to 12 per cent. of sinc. The table is by Hoyman.

Brown-O'Hara, Ropp, etc., would serve no useful purpose. However, a comparison of Huntington-Heberlein pots and Dwight-Lloyd roasters, made at a works where both are used, is of the utmost interest.

Such a comparison was made by W. W. Norton, regarding the plant at Murray, Utah, at the Salt Lake meeting of the A. I. M.

E., August, 1914.

Sulphur Limits of Roasting Equipments

At the Murray plant, modern roasting practice is fully exemplified and there are now in successful operation roasting furnaces or devices of several sorts; namely, Godfrey revolvinghearth furnaces, Wedge multiple-hearth mechanical roasters, DWIGHT-LLOYD sintering machines, and HUNTINGTON-HEBER-LEIN pots. Godfrey and Wedge furnaces will properly handle material high in sulphur, say ores with 25, 30 and 35 per cent. of that element; D. & L. machines and H. & H. pots will positively not treat efficiently ores or mixtures containing anywhere near the sulphur content mentioned, but are confined to charges containing from 15 to 18 per cent. In passing, it may also be explained that, so far as the knowledge of the writer goes, GODFREY and WEDGE furnaces do not economically eliminate sulphur to an extent sufficiently low for lead-smelting practice. With these simple facts in mind, it will be perfectly clear to all that the metallurgist in charge may elect to treat sulphide ores in either of two ways: He may preroast in GodFrey and Wedge furnaces and subject the partly roasted product to a final treatment on D. & L. machines and H. & H. pots, or he may dilute the average sulphur in the raw ore to 15 or 18 per cent. by means of an admixture of the requisite quantity of non-sulphur fines and send the mixture thus obtained to D. & L. and H. & H. The Murray plant does both. A certain flexibility is thus afforded for a segregation of the various classes of sulphide ores; moreover, in the matter of oxide fines, one limit screening operations to a point deemed best metallurgically.

GODFREY and WEDGE furnaces are essentially preroasters; D. & L. machines and H. & H. pots are final roasters. At

Murray all final roast is either D. & L. or H. & H.

Cost of Installation

The Murray plant is equipped with two D. & L. machines, the total daily capacity of which may be stated at 220 tons, and 23 H. & H. pots, with capacity of 400 tons. It would, of course, be manifestly unfair to compare directly the total costs of these two installations, but it seems quite safe to say that for almost any given tonnage capacity a D. & L. plant can be built for considerably less than an H. & H. plant, it being understood that by H. & H. is meant the converting-pot portion of an installation only, with no reference to Godfrey furnaces. In the case of the H. & H. one must have heavy cast-iron pots for handling ore in comparatively large units, expensive overhead

handling crane, substantial cooling floor, and, finally, a crusher which the D. & L. does not require. The cost of the installation item must be put down in favor of the D. & L. plant.

Cost of Roasting

Any discussion of roasting costs should, of course, be based on units of sulphur eliminated. In a general way, our experience has shown that the D. & L. will reduce an initial sulphur of about 15 or 16 per cent. to about 4 per cent. in the roasted product, while the H. & H. is capable of handling a slightly higher initial sulphur, say 17 or 18 per cent. with resultant 5 per cent. in product. During a recent period of 47 consecutive days, it is known that units of sulphur eliminated per ton of charge at the D. & L. practically equaled units of sulphur eliminated per ton of H. & H., and it is probable that an exhaustive examination of Murray plant roasting records would show about the same amount of sulphur per ton of charge driven off as between the two sorts of roasters now under review. It follows that figures representing costs of roasting are truly comparable.

The limitations of this paper will not permit of a detailed review of roasting costs, but it may be stated that during the entire year 1913 the H. & H. made the better showing to the extent of about 5 cts. per ton roasted, and for the first 3 months of 1914 the H. & H. also had an advantage of about 3 cts. per ton. Murray experience, everything considered, indicates slightly lower costs for H. & H., as compared with D. & L., but the fact that all calculations are based on operations at an H. & H. plant having twice the capacity of the D. & L. plant

must not be overlooked.

Wide Range of Charge

Any intelligent discussion of analysis of raw charge to roasters should have the fundamental thought in mind that the metal-lurgist must treat what comes to the plant. He cannot always be favored with the proportions of silica, iron and lead which would give the best results, consequently the adaptability of any given roasting device to a variety of materials will be

accepted as an item of far-reaching importance.

Two or three years ago, in connection with a visit to three or four custom lead-smelting works newly equipped with D. & L. machines, the writer was somewhat impressed with the limitations placed on the charge the machines were capable of handling. Inquiry brought forth the information that certain sorts of materials could be attempted only by resort to a special layer of fine limestone or other infusible material carried next to the grates; any percentage of raw matte at all seemed out of the question; zinc was naturally "side-stepped" as highly deleterious; much stress was placed upon the proportion of silica to the iron, and nearly all the enthusiasts demanded a goodly percentage of lead provided a choice quality of sinter was to be in evidence. Of late, however, the staff at Murray have found that a wide range of mixtures may be efficiently handled over

the D. & L., and have no doubt that equally good progress has been accomplished at other works. Preroasted ore, any kind of raw sulphide ore or concentrates, flue dust, preroasted matte, or even raw matte may be combined in certain proportions and successfully sintered over these machines. A sufficient quantity of non-sulphur diluent to bring the average of the mixture down to 16 per cent. sulphur must always be added and, of course, the details of operation must be cared for. However, equally satis-

factory results have been attained with H. & H. pots.

Turning now to physical character of the raw ore, it is, of course, recognized that the air currents are required to permeate

course, recognized that the air currents are required to permeate a thin layer of charge in case of D. & L. treatment, whereas the pot roasters are committed to a much thicker layer; but a physically fine charge will restrict tonnage on D. & L. just as surely as it will in H. & H. pots, although the D. & L. process is able to treat slimes or rather fine material which it would be wholly useless to attempt to treat in the H. & H. By way of summing up, it may be stated that the D. & L. process possesses a slight advantage over the H. & H. in the matter of flexibility or range of charge, because the D. & L. permits more delicate application of operating details which are essential to success; also extremely fine materials find no proper place in the H. & H. charge.

Lead Losses

We have certain data at hand showing a moderate lead loss on D. & L. machines, these data being based on standard operating conditions during which the resultant gases and fumes were sampled and analyzed. No data available covering losses with H. & H. pots. The expense and difficulties in connection with accurately sampling an H. & H. output of 400 tons per day need not be pointed out and gas measurements and samples taken from the combined gases of 23 pots on two different main flues might eventuate in metal-recovery data not wholly dependable. . . . It is regarded as doubtful if the D. & L. process is productive of any lower metal losses than is the H. & H. process.

Physical Condition of Product

Final-roasting treatment results in a sintered or agglomerated product, and material of a desirable physical character is passed along to the blast furnaces. The D. & L. sinter is usually of a porous or cellular structure; the H. & H. tends to greater density or firmness. Published and unpublished opinions of metal-lurgists have sought to show that the peculiarly open or cokelike structure of the D. & L. sinter carried with it certain extraordinarily favorable properties when subjected to the smelting process in the blast furnace, and have even claimed appreciable saving in the coke percentage used for smelting. Rather exaggerated ideas concerning the efficiency of an exposure of porous surfaces to contact with reducing gases have been advanced and intimate mixtures (possibly intimately combined

silica and lead) have been proclaimed as "predigested," and therefore more easily reduced. The writer believes that a partly fused or "predigested" combination may tend to poor results rather than to good results when smelted, for the reason that such substances fuse at too low a temperature in the furnace. Certain writers have gone so far as to examine the cell structures of the D. & L. product microscopically and have declared that glazed or unglazed surfaces have a bearing upon the readiness with which the products were later reduced in furnaces.

With all due respect to the theories above set forth, it was considered that more dependable conclusions could be drawn by means of actual operating tests and accordingly the MURRAY furnaces during 5 days of August, 1912, were run on two charges, the one containing no D. & L. roast at all, the other

Test Charges With and Without D. & L. Sinter

	Furnaces 1, 3, 7 and 8 (No D. & L.)	Furnace 5 (D. & L.)
Coke, 920 (11½ per cent.)	2970 2000	320
D. & L. roast	600 690 1640	4800 400 540 1840 100
Total	8000 Per cent. 0.63 10.7	8000 Per cent. 0.91 14.96

containing a rather large amount of this material. It was believed that any peculiar virtue existing in D. & L. product would have abundant opportunity to make itself manifest. The exact charges used are given above, together with the average lead in resultant slag and matte.

Great pains were used to make the experimental run one of value. The D. & L. roasted product was of a typically honeycombed character. No. 5 furnace was in excellent condition, its operations were closely watched by the metallurgist in charge of the furnaces and by the writer, yet absolutely no strengthening of reduction appeared. On the contrary, No. 5 did worse than the other furnaces.

General blast-furnace experience covering a wide range of charges and a considerable period of time indicates that no particular effect, either good or bad, can be claimed for D. & L. sinter as relating to strength of reduction during the smelting process, and exactly the same remark will apply to H. & H. agglomerated material. (Of course, the D. & L. sintered cakes must be broken to the proper size and the H. & H. material must be crushed suitably small, or distinctly bad reduction will

ensue.) That both of these products of modern roasting development help the speed of furnaces enormously is certainly a fact. The final roasters of modern smelters, in supplanting the old hand roasters and fine-ore-producing mechanical furnaces, have very naturally served to increase blast-furnace

tonnages to a remarkable extent.

As to which product is the better physically, that is to say, which will produce the heavier tonnage at blast furnaces, a first-class D. & L. sinter does not excel a first-class H. & H. agglomerated product. Moreover, given an inferior quality of both, it would seem that the admittedly cellular or at times fragile D. & L. can hardly equal the more firm and stable H. & H. Here, again, however, real experience at blast furnaces may outweigh mere conjecture or theorizing, so the following data are submitted with the idea of showing that in this instance at least the physical character of the D. & L. produced no better tonnage at blast furnaces than did the physical character of the H. & H. On Aug. 12 and 13, 1912, the following two charges were smelted side by side with the same coke percentage, the same blast pressure and as near like conditions in other respects as it was possible to obtain:

	Furnaces 1, 3 and 5 (H. & H.)	Furnaces 7 and 8 (D. & L.)
Coke, 920 (11½ per cent.)	1400 j	2060
D. & L. roast. Hand-roasted matte. Iron ore. Limestone. Scrap iron.		3000 400 580 1860 100
Total	8000 294 Per cent. 0.81 13.47	8000 287 Per cent 1.03 13.0

Conclusions

It is believed that a fair summary of the actual experience set forth in this paper would be as follows:

	Advantage in favor of
Cost of installation	D. & L.
Cost of roasting	H. & H.
Adaptability of charge	D. & L.
Metal losses	Doubtful
Physical condition of product	H. & H.

This article is unable to point out any overwhelming advantage of the D. & L. over the H. & H. system, although continued progress may upset the balance at any time. If history repeats

itself some new roasting system will take rank over both within a

few years.

Copper Roasting.—The cement kiln and DWIGHT-LLOYD are both being used on flotation concentrates, which apparently are the most troublesome item with which the roaster has to deal. The Wedge, Herreshoff and McDougal furnaces are being used on larger material. What any one of them will do on an unknown ore seems to be mainly a matter of experiment.

The table on p. 516 gives some working data.

Lead Roasting Furnace Dimensions¹

LONG-BEDDED HAND-ROASTING FURNACE WITH LEVEL HEARTH

	I.	II	III
Length of hearth	60′	66′	75'
Width of hearth		16'	14'
Hearth area, sq. ft		1056	1150
Length of grate	l 8'	7' 9"	8′
Width of grate		2' 6"	3' 6"
Grate area, sq. ft	14.62	19.4	28
Ratio hearth to grate area		54.5:1	41:1
Space above fire bridge, length		,	
and width	7'9"×2' 2"	7' 9"×2' 2"	2' 6"×1'
Space above flue bridge, length			- 0 //-
width	No flue bridge	4' 2"×8"	No flue bridge
Height of fire bridge above hearth	14"	12"	20′′
Height of roof above fire bridge	18"	20''	12"
Height of flue bridge above hearth		6"	
Height of roof above flue bridge.		15"	
Depth of grate below top of			
bridge	14"	15"	17''
(1/3 galena	Matte	Pyritic
Character of ore	3's pyrite	Concentration	
Depth of charge near flue bridge.	3-4"		5"
Time ore remains in furnace, hr	32	24	24
Tons of raw ore per 24 hr	8.1	12	وُ
Lb. ore roasted sq. ft. of hearth			
area	20	21.8	15.65
Character of roasted ore		Pulverulent	Partly
	sintered	- with the care and	sintered
Per cent. S in roasted ore	12	2-5	3

Brick used. Clay brick inside, red brick or second-class clay brick. Average thickness of side walls, 18 to 30 in. Thickness of roof, 9-15 in.

Roasting Table 3

1 kg. FeS	becomes 0.909 kg. Fe ₂ O ₃
1 kg. FeS ₂	becomes 0.667 kg. Fe ₂ O ₃
1 kg. PbS	becomes 1.268 kg. PbSO ₄
1 kg. CaCO:	becomes 0.560 kg. CaO
1 kg. MgCO:	becomes 0.476 kg. MgO

^{1 &}quot;Metallurgy of Lead," H. O. HOFMAN.
2 Not clear how this figure is obtained.
3 INGALLS, "Metallurgy of Zinc."

LENGTH OF TIME CONSUMED IN BURNING HEAPS OF VARIOUS Heights1

Height in feet	Quality of ore	Sample number	Per cent. sulphur	Per cent. copper	Days burning
5 5 5 5 5 5 5 5 5 6 6 6 7 7	Pyrite. Chalcopyrite. Bornite and pyrite. Copper glance and pyrite in quarts.	1 2 3 1 2 3 1 3 1 3	39 18 31 39 18 31 39 18 31 39	636 14.3 21.4 6.5 14.3 21.4 6.5 14.3 21.4 21.4	54 41 53 66 50 65 72 61 74 94 86

IGNITION AND INCANDESCENCE TEMPERATURES, DEG. C., OF SOME METALLIC SULPHIDES, HEATED IN AIR²

Material	Size of grain	First notice of SO2	Incan- descence
Pyrite	II II	325 405 472	533
Pyrrhotite	I III III	430 525 590	595
Nickel sulphide,	II	700 802	
S, 26.7 Cobalt sulphide	III I II	886 574 684	
S, 33.63 Cobalt sulphide	III I	859 514	• • • • • • • • • •
Co, 70.20 S, 29.80 Stibnite	III	751 1019 200	850
Molybdenite	ΙΙΪ	340 240	
Cinnabar	III I III	508 338	• • • • • • • • • • • • • • • • • • • •
Chalcocite	III III	420 430 679	
Bismuth sulphide	III	500 626	
Manganese sulphide, Mn, 61.01, Fe, 2.02, 8, 33.98 Argentite.	III	355 700 605	
Blende	IIÎ I	875 647	
Galena (a)	III I III	810 573 616	
Millerite	III	573 616	

¹ PETERS, "Modern Copper Smelting."

² HOFMAN, "General Metallurgy," p. 404.

I = 0.1 mm.

II = 0.1 to 0.2 mm.

III = over 0.2 mm.

⁽a) In oxygen.

Dissociation Temperatures of Certain Earths and Salts

The following dissociation temperatures were obtained by W. Hempel and C. Schubert, and were determined by heating in an electric oven and determining the end points by the evolved gas volumes. The temperatures were determined with a Le-Chateler pyrometer. (See also p. 291.)

Material	Beginning of decomposition	End of decomposition
Brown iron ore	470–500°C.	1280°C.
Hematite		1500
Lead peroxide	290	640
Potassium permanganate	160	1400
Potassium bichromate	600	1150
Lead chromate		1500
Potassium nitrate	400	950
Sodium nitrate	380	725
Spathic iron ore	470	880
Strontianite	1075	1340
Magnesite		900
Blende	150-175	360
Pyrite	480	over 1400
Copper sulphide		550
Arsenical pyrites	220	
Copper pyrites		720°

Efficiency of Roasting Apparatus¹

. Apparatus	Lb. ore treated in 24 hr. per sq. ft. of hearth area	Character of product for blast-furnace smelting
I. Roast heaps and stallsII. Reverberatory roasters:	5–20	Good.
1. Hand furnaces	24-35	Fair.
Average conditions	33-75	Too fine.
Special conditions	150	Too fine.
3. Revolving cylinders	128	Too fine.
III. Blast-roasting pots, range	500–900	Excellent.
Blast-roasting pots, excellent	600	Excellent.
IV. Blast-roasting, thin layers: Dwight-Lloyd system		
1. Intermittent down-draft pans.	1000-2000	Excellent.
2. Continuous sintering machines	2200-3000	Excellent.

¹ Hofman, "General Metallurgy," p. 433.

Metallurgical Slags

In metallurgy, slagging is the formation, at elevated temperatures, of any fluid or semi-fluid mass, with the separation from it of a metal or metalloidal residue. Slags may be waste products, as in lead, iron or copper smelting in the blast furnace, or they may be extremely rich products which must be retreated, as the slags from copper-refining furnaces or from alimea smelting.

The ordinary constituents of the metallurgist's slags may be

grouped as follows:

Bases: FeO, CaO, Cu₂O, PbO, MnO, ZnO, MgO, BaO, K₂O, Na₂O, Al₂O₂ (sometimes).

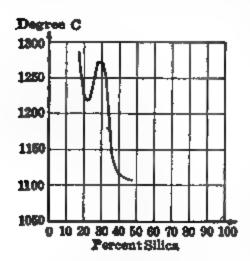
Protecting agents: S, As, Sb, Te, Se.

Reducing agents: C, S.

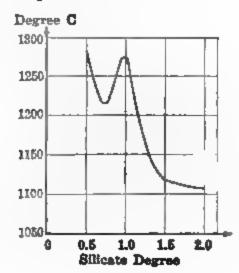
Acids: SiO₂, Al₂O₂ (sometimes).

Neutral solvents: CaF₁, Na₂CO₂, K₂CO₂, CaCl₂, borates. Slag Degree.—The metallurgist names his slag by the relative amounts of oxygen combined with acid and base. a bisilicate slag is FeO·SiO₁, since there is twice the oxygen combined with the silica as with the iron. It follows, then, that the bisilicate of the metallurgist is the silicate of the chemist. A metallurgical monosilicate is (FeO)₂·SiO₂; a sesquisilicate (FeO)4 (SiO2)1.

Iron.—Within reasonable limits, the larger the amount of iron the more fusible the slag. Slags rich in iron are dangerous in a lead furnace, as high iron seems to promote the formation of



Formation temperatures of ferrous silicates. (Horman)

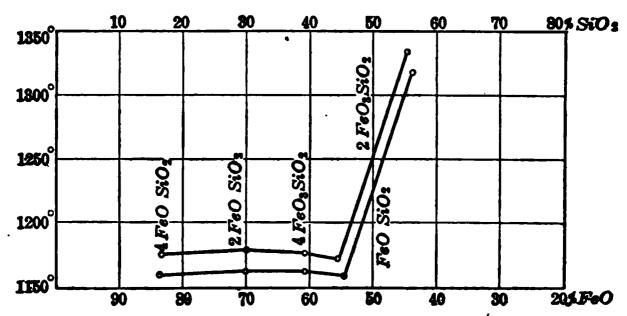


Formation temperatures of ferrous silicates, (HOPMAN)

But high iron is considered a necessity, by some, when zinc is present, as it is said high iron promotes the solution of ZnO.

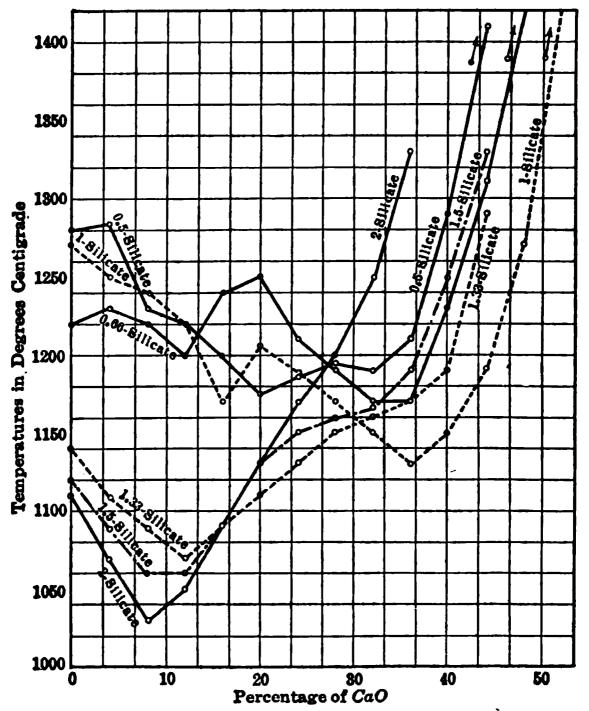
Pyrite—loses one atom of sulphur and enters the matte to the extent of 70 per cent. or over, except in pyritic smelting.

Manganese.—In general its effects are similar to iron, but it



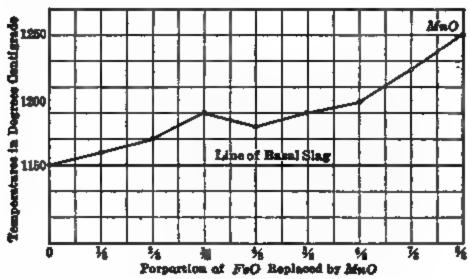
Formation temperatures of ferrous silicates.

Lower line—Sintering temperatures.
Upper line—Temperatures of complete fusion.



Formation temperatures of some ferrous-calcic silicates.

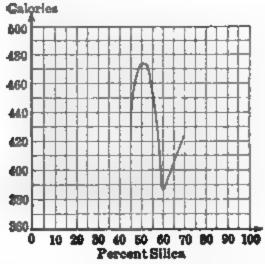
makes a less fusible and more liquid slag than iron. It should be used with as acid slags as are economical. It seems to carry silver into the slag. It reduces the dissolving power of the



Formation temperatures as affected by substitution of MaO for FeO. The slag was a singulo-silicate, SiO₂, 30.1 per cent.; FeO, 35.9 per cent.; CaO, 32 per cent.

slag for sine oxide, magnesia and barium sulphide. The luster of an Mn slag is usually glassy and small particles are attracted by a magnet.

Lime and Magnesia.—Lime decreases (after a certain point) both the fusibility and the specific gravity of slags. In lead



Total heats of solidification of calcium silicates.

amelting it seems to inhibit the formation of speiss and matte. It is said to enter mattes as CaS. Burnt lime seems to offer no advantage over limestone. Magnesia replaces lime to a con-

siderable extent, but magnesia and zinc are incompatibles. The Mg slags usually do not flow well.

Fluorspar—forms extremely fusible slags and will dissolve

anything.

Alumina—apparently acts as a base if much silica is present, as an acid if the silica is low, always as a nuisance. In my own work it has seemed to make a most unhappy mixture with high magnesia. Some successful slags with high alumina are given on p. 511. It may be only an accident that they were successful. In iron practice the upper limit of alumina seems to be reached, according to J. E. Johnson, Jr., at about 13-14 per cent. MENK of the Shenango Furnace Co. has run slags carrying 18-23 per cent. of Al₂O₃, but they were tough and pasty, and coke consumption was high. On the other hand, a slag carrying 10-15 per cent. of Al₂O₃ usually is a better running slag than one carrying only 7. That is, there is a lower danger line as well as an upper.

Barium.—It enters slag as silicate and matte as sulphide, making the former heavy, the latter light, and thereby hindering settling. A barium-iron slag is usually not very fluid, is opaque, steel gray to black, with vitreous luster, and usually is strongly

magnetic.

Blende and zinc oxide—cause more difficulty in the blast furnace than anything else. ZnS in the matte lowers its fusibility; ZnO in the slag renders it less fusible. (It goes to slag and matte in about equal proportions.) It carries other metallic sulphides into the slag, and makes furnace accre-It is most disastrous in combination with magnesia and alumina.

Successful high-zinc slags in lead smelting are said to have been:1

RECOMMENDED	LEAD	SLAGS	CARRYING	High	Zinc ²
					_

$egin{array}{lll} SiO_2. & \dots & \\ FeO. & \dots & \\ CaO. & \dots & \\ ZnO. & \dots & \end{array}$	33.9	29.0	33.4	31.5	29.4	32.1	26.5	22.7
	14.8	14.0	14.4	19.0	24.5	19.0	24.3	24.8
Total	93.2	88.5	93.6	92.5	92.9	92.1	91.9	94.9

Arsenic, antimony, selenium and tellurium—tend to form speiss; are of more trouble in the subsequent refining than in smelting, except in so far as they volatilize easily and tend to carry off other metals.

Specific Gravities of Slag-forming Compounds³

Singulo-silicates of iron, manganese and zinc, about 4. Bisilicates of iron, manganese and zinc, about 3.5. The basic silicates of alumina, from 3.2 to 3.4. The acid silicates of alumina, from 3 to 3.2,

The acid smooder.

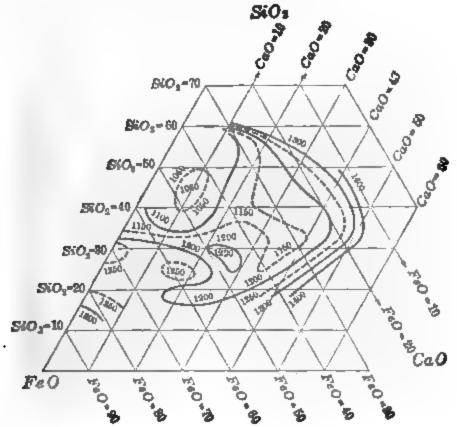
1 Hosman, "Metallurgy of Lead."

2 FURMAN's "Manual of Assaying."

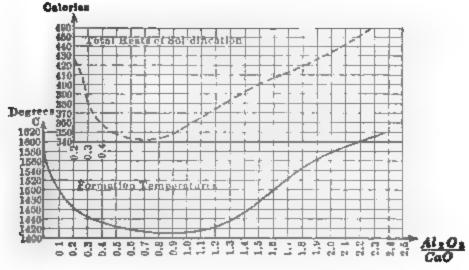
2 FURMAN's "General Metallurgy," p. 74.

Silicates of magnesia, from 3 to 3.3. Silicates of lime, from 2.6 to 3.

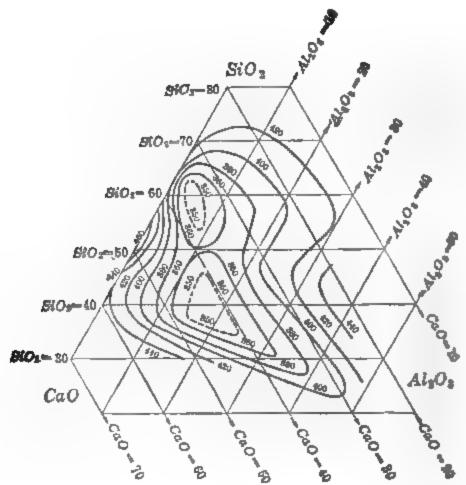
Alkaline silicates, about 2.5. Uncombined silica, 2.6. Bisilicate of barium, 4.4. Silicate of lead, 7. Ferrous sulphide, 4.8. Calcium sulphide, 4. Magnetic oxide, 5. Sulphate of barium, 4.5.



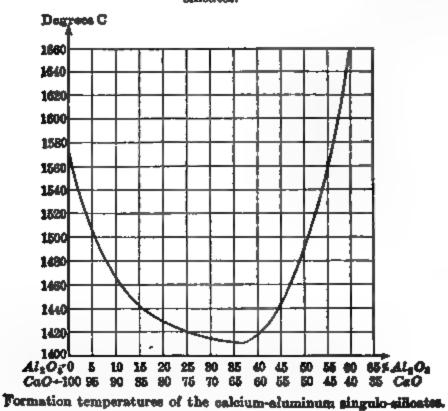
Triaxial diagram of some ferrous-calcium silicates. (Hofman-Bary)

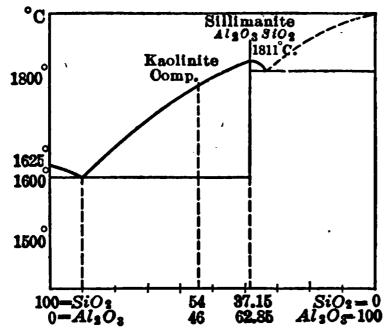


Formation temperatures and total heats of solidification of the calciumaluminum singulo-silicates.

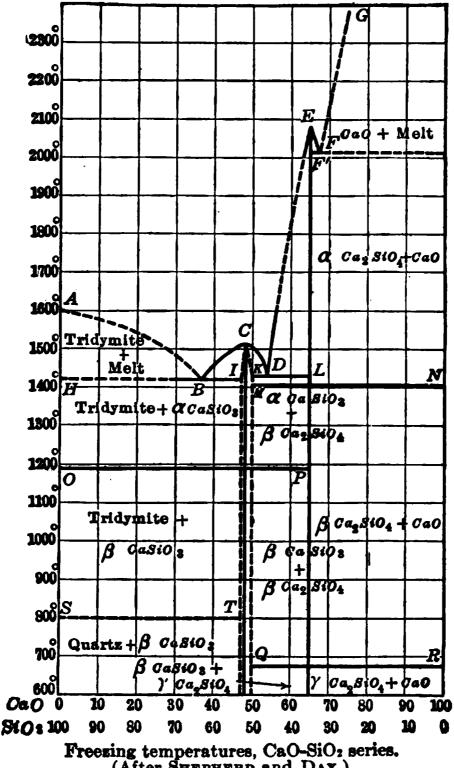


Triaxial diagram of total heats of solidification of calcium-aluminum silicates.





Formation temperatures, Al₂O₂-SiO₂ series. (After Shepherd and Rankine.)

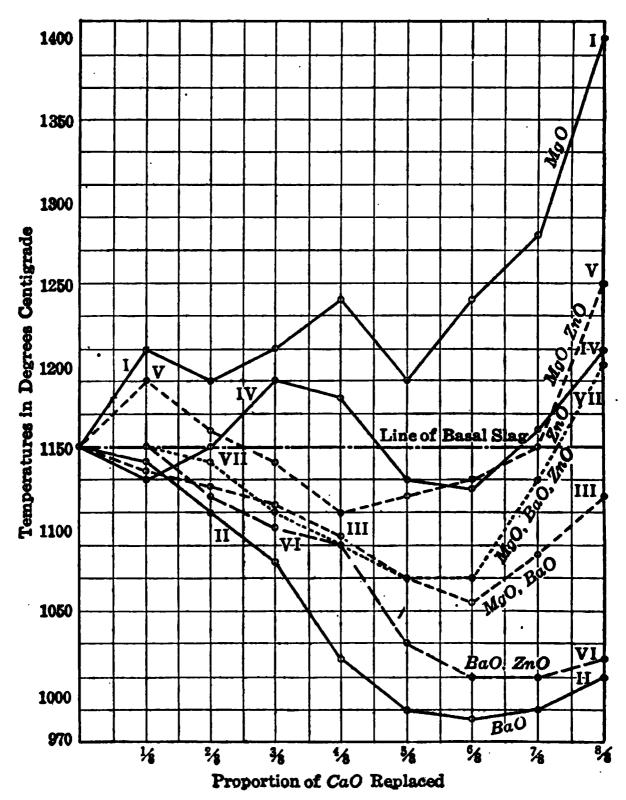


Freezing temperatures, CaO-SiO₂ series. (After Shepherd and Day.)

Matte Smelting¹

In order of decreasing affinity for sulphur² the chief metals stand thus according to

FOURNET: Cu, Fe, CoNi, Sn, Zn, Pb, Ag, Hg, Au, As, Sb. Shütz: Mn, Cu, Ni, Fe, Sn, Zn, Pb. 1



Formation temperatures as affected by replacement of CaO by MgO, BaO, ZnO.

The slag was a singulo-silicate, SiO₂, 30.1 per cent.; FeO, 35.9 per cent.; CaO, 32 per cent.

¹ Hofman's "General Metallurgy," p. 74.

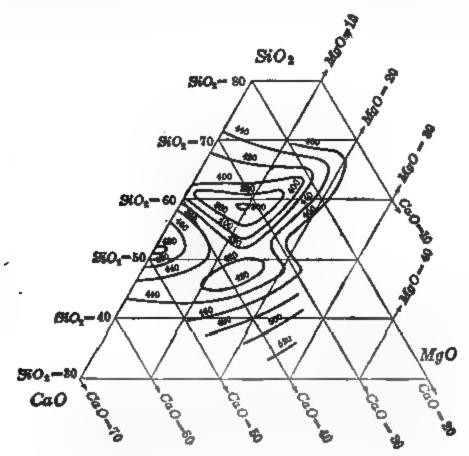
² But in a wet way Schurmann places the sulphides in the following order as regards the rate at which they are decomposed by the nitrates, sulphates and chlorides of other metals: Pd, Hg, Ag, Cu, Bi, Cd, Sb, Sn, Pb, Zn, Ni, Co, Fe, As, Tl, Mn. Thus PdS is not decomposed by the salts of any of the other metals, while PdCl₂ converts the sulphides of the other metals into chlorides. With MnS, this is decomposed by salts of any of the other metals, while MnSO₄ has no decomposing effect.

Specific Gravities of Matte-forming Compounds1

Substances having a specific gravity not greater than 4.7: the sulphides of zinc, molybdenum, calcium and manganese.

Substances having a specific gravity between 4.7 and 5.5¢ the sulphides of barium, iron, cadmium, nickel, cobalt, and copper; and the magnetic oxide of iron.

Substances with specific gravities from 6 to 9: the sulphides of silver, lead and bismuth; the arsenides and antimonides; and



Triaxial diagram, heats of solidification of the calcium-magnesium silicates.

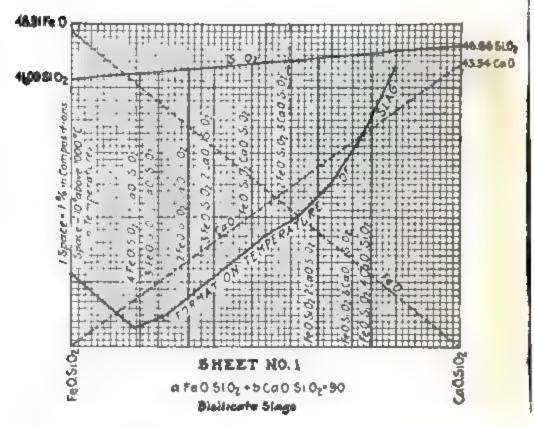
the sulpharsenides and sulphantimonides of silver, copper, bismuth, lead, iron, cobalt and nickel; and metallic lead, iron and copper.

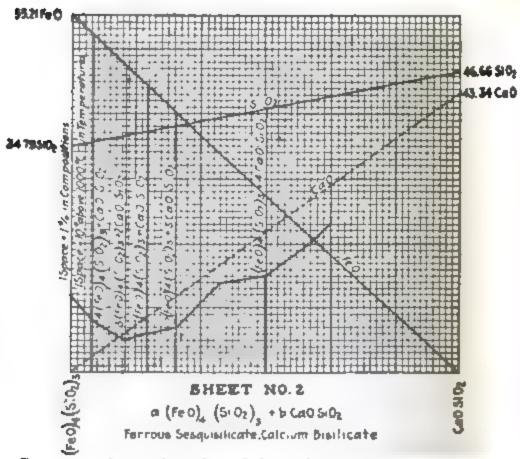
Formation-Temperature Charts

In the illustrations on pp. 506-509 are plotted certain type mixtures of ferrous-calcium silicates and silicate-aluminates, calculated to a basis of $CaO + FeO + SiO_2 = 90$, together with the formation temperature corresponding to the mixture. To use these, determine the general type to which the slag corresponds, and then find the ordinate corresponding most closely to its composition, and read the formation temperature on the ordinate.

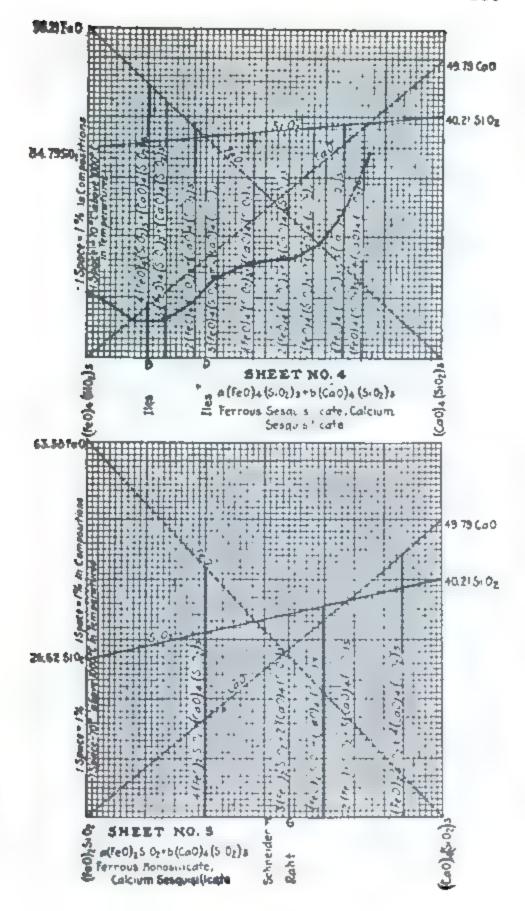
² Hofman's "General Metallurgy," p. 74.

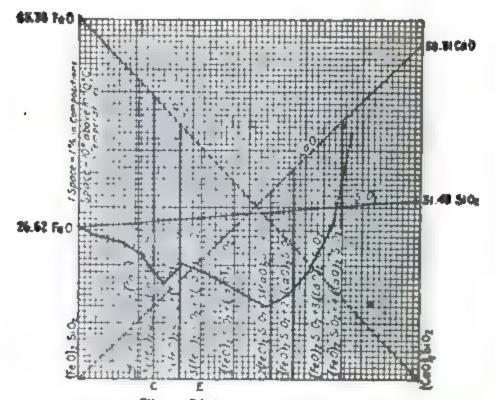
534 METALLURGISTS AND CHEMISTS' HANDBOOK

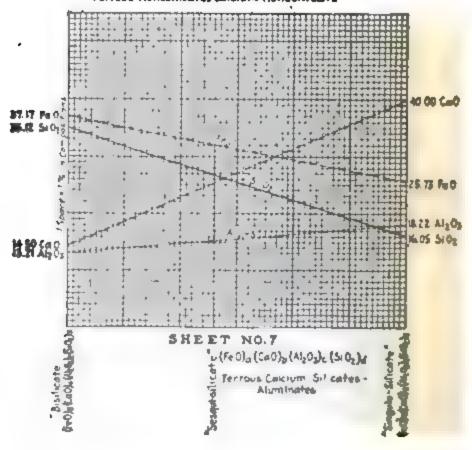


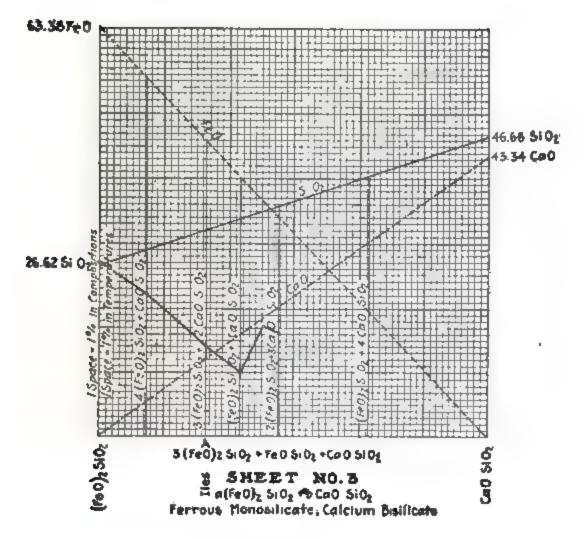


See p. 505 for explanation of these charts.









Metallurgical Factors¹ ORTHOBILICATE SLAGS

To use the tables on page 511 for metasilicates, CaSiO₂, Na₂SiO₂, etc., double the amount of silica found in the table.

To use it for mesosilicates (CaO)₂ (SiO₂)₂, (Na₂)₄ (SiO₂)₃, etc., increase by one-third the amount of silica in the table.

¹ From H. L. While's "Chemical Calculations," Henry Holt & Co., New York.

Given	Re- quired	To make	Factor	Given	Re- quired	To make	Factor
AlsOs BaO BaSOs CaO CaCOs CaSOs	SiO ₂ SiO ₂ SiO ₂ SiO ₂ SiO ₃	Al ₄ (SiO ₄) ₂ Ba ₂ SiO ₄ Ba ₂ SiO ₄ Ca ₂ SiO ₄ Ca ₂ SiO ₄	0.8865 0.1969 0.1294 0.5383 0.3017	FeS: K:O MgO	8iO ₂ 8iO ₂ 8iO ₂ 8iO ₂	Fe ₂ SiO ₄ Fe ₂ SiO ₄ K ₄ SiO ₄ Mg ₂ SiO ₄ Mg ₂ SiO ₄	0.3433 0.2516 0.3203 0.7483 0.3580
2H ₂ O Cu CuO Fe FeO Fe ₂ O ₂ Fe ₂ O ₄	SiO ₂ SiO ₂ SiO ₂ SiO ₂ SiO ₂ SiO ₂	Ca ₂ SiO ₄ Cu ₄ SiO ₄ Cu ₄ SiO ₄ Fe ₂ SiO ₄ Fe ₂ SiO ₄ Fe ₂ SiO ₄ Fe ₂ SiO ₄	0.1754 0.2374 0.1897 0.5403 0.4200 0.3780 0.3910	MnO Na ₂ O Pb PbO Zn	SiO ₂ SiO ₂ SiO ₂ SiO ₂ SiO ₂ SiO ₂	Mn ₂ SiO ₄ Mn ₂ SiO ₄ Na ₄ SiO ₄ Pb ₂ SiO ₄ Pb ₂ SiO ₄ Zn ₂ SiO ₄ Zn ₂ SiO ₄	0.5491 0.4254 0.4863 0.1460 0.1355 0.4618 0.3710

To use the following table for metasilicates, (M"SiO₂) halve the amount of basic substance found by the table.

To use it for mesosilicates, (M"O)₃ (SiO₂)₂ decrease by one-quarter the amount found by the table.

8iO ₂	Al ₂ O ₂	Al4(SiQ4):	1.128	SiO ₂	K ₂ CO ₃	K48iO4	4.579
8iO2	BaO	Ba ₂ SiO ₄	5.080	SiO ₂	MgO	Mg:SiO4	1.336
SiO2	BaSO ₄	Ba2SiO4	7.730	SiO ₂	MgCO:		2.793
SiO ₂	CaO	Ca ₂ SiO ₄	1.858	SiO ₂	Mn	Mn ₂ SiO ₄	1.821
SiO ₂	CaCO ₂	Ca ₂ SiO ₄	3.315	SiO ₂	MnO	Mn ₂ SiO ₄	2.351
SiO ₂	CaSO4				1	_	
	2H ₂ O	Ca ₂ SiO ₄	5.202	SiO ₂	Na ₂ CO ₂	Na ₄ SiO ₄	3.513
8i0 ₂	Cu	Cu ₂ SiO ₄	4.212	SiO ₂	Pb	Pb ₂ SiO ₄	6.851
SiO ₂	CuO	Cu ₂ SiO ₄	5.271	SiO ₂	PbO	Pb2SiO4	7.381
SiO ₂	Fe	Fe ₂ SiO ₄	1.851	SiO2	Zn	Zn2SiO4	2.166
SiO ₂	FeO	Fe ₂ SiO ₄	2.381	SiO ₂	ZnO	Zn2SiO4	2.695
SiO ₂	Fe ₂ O ₃	Fe ₂ SiO ₄	2.646	~~~			
ŠiÖ:	Fe ₂ O ₄	Fe ₂ SiO ₄	2.557		1 1		
ŠiŎ:	FeS	Fe ₂ SiO ₄	2.913		}		
SiO ₂	FeS.	Fe ₂ SiO ₄	3.974		1		
2103	1.603	1,630104	9.814	ł	1		

SULPHIDES

Given	Required	Factor	Given	Required	Factor
Cu Cu ₂ S Cu ₂ S Fe Fe FeS FeS FeS	Cu:S S (to make Cu:S) Cu S FeS S (to make FeS) Fe S Fe:O:	1.252 0.2520 0.7987 0.2013 1.574 0.5735 0.6355 0.3645 0.9084	Pb PbS PbS	S (total) FeS (FeS:=FeS+S) PbS Pb Fe (PbS+Fe= FeS+Pb) Cu (to make Cu:S) Cu:S FeS FesO: (required for FeS)	0.5342 0.7329 1.155 0.8658 0.2339 3.968 4.968 2.744 2.493

ALUMINA SLAGS (ACCORDING TO HENRICH)

	SiO ₂	Al ₂ O ₂	FeO	CaO
"Singulo" slag (FeO)4 (CaO)8 (Al2O3)2 (SiO2)3. "Sesqui" slag (FeO)6 (CaO)6 (Al2O3)2 (Si O2)6. "Bi" slag (FeO)8 (CaO)4 (Al2O3)2 (SiO2)9	16.05	18.22	25.73	40.00
	27.15	15.31	32.32	25.22
	35.12	13.21	37.17	14.50

SOME PYRITIC SLAGS¹

Made by	SiO ₂	Fe	Al ₂ O ₃	CaO	MgO	Ag	Cu
Walter E. Koch. F. R. Carpenter. W. H. Nutting. W. H. Freeland. Wm. A. Heywood.	33.5	32.26	5-7 2.00 1 1.54 4.84	5-15 11.42 18.0 8.24 6.30	2-5 3.44 1.37	0.24	0.27 0.35 0.4

Balling's Tables from "Compendium der Metallurgischen Chemie"

One part by weight of silica requires	Parts by weight of bases	One part by weight of bases requires	Parts by weight of silica
For Singulo-silicates	1.00	For Singulo-silicates	0.700
Lime	1.86	Lime	0.538
Magnesia		Magnesia	0.748
Alumina	1.13	Alumina	0.886
Ferrous oxide	2.38	Ferrous oxide	0.420
Manganous oxide	2.35	Manganous oxide	0.425
For Bi-silicates		For Bi-silicates	ļ
Lime	0.93	Lime	1.077
Magnesia	0.67	Magnesia	1.497
Alumina	0.56	Alumina	1.773
Ferrous oxide	1.19	Ferrous oxide	0.841
Manganous oxide	1.18	Manganous oxide	0.851
For Sesqui-silicates		For Sesqui-silicates	0,000
Lime	1.24	Lime	0.806
Magnesia	• • • •	Magnesia	1.122
Alumina	0.75	Alumina	1.330
Ferrous oxide	1.59	Ferrous oxide	0.630
Manganous oxide	1.57	Manganous oxide	0.638

¹ T. A. RICKARD'S "Pyritic Smelting."

Balling's Table for Alumina as Acid To form (MO): Al₂O:

1 part Al ₂ O ₄ requ	ires parts of	1 part of base rec	uires parts Al
MgO CaO MnO FeO ZnO BaO Na ₂ O K ₂ O	1.72 2.47 3.03 3.07 3.48 6.56 2.65 4.03	MgO	0.580 0.417 0.330 0.325 0.287 0.153 0.377 0.248

I. AUXILIARY TABLES TO ACCOMPANY BALLING'S SLAG TABLE

Formula .	Mol. wt.	Log.
(MgO) ₄ SiO ₂	221.84	2.34604
(CaO) SiO2	284.8	2.45454
$(MnO)_4SiO_2$	344.4	2.53706
$(FeO)_4SiO_2$	348.0	2.54158
$(BaO)_4SiO_2$	674.0	2.82866
$(MgO)_3SiO_2$	181.48	2.25883
$(CaO)_8SiO_2$	228.7	2.35927
$(MnO)_3SiO_2$	273.4	2.43680
$(FeO)_3SiO_2$	276.1	2.44107
(BaO) ₃ SiO ₂	520.6	2.71650
$(MgO)_2SiO_2$	141.12	2.14959
$(CaO)_2SiO_2$	172.6	2.23704
$(MnO)_2SiO_2$	202.4	2.30621
$(FeO)_2SiO_2$	204.2	2.31006
$(BaO)_2SiO_2$	367 .2	2.56490
$(MgO)_4(SiO_2)_3$	342.64	2.53484
(CaO) 4 (SiO2) 3	4 05.6	2.60810
$(MnO)_4(SiO_2)_3$	465 .2	2.66755
$(FeO)_4(\dot{S}iO_2)_3$	468.8	2.67099
$(BaO)_4(SiO_2)_3$	794.8	2.90026
MgOSiO ₂	100.76	2.00329
CaOSiO ₂	116.5	2.06633
MnOSiO ₂	131.4	2.11860
FeOSiO ₂	132.3	2.12156
BaOSiO ₂	213.8	2.33001

II. RATIOS OF MOLECULAR WEIGHTS

$ \begin{array}{c} \text{CaSiO}_{3} \\ 1.000 \\ \text{Ca}_{4}\text{Si}_{3}\text{O}_{10} \\ 1.000 \\ \text{Ca}_{2}\text{SiO}_{4} \end{array} $	FeSiO ₃ 1.136 Fe ₄ Si ₃ O ₁₀ 1.156 Fe ₂ SiO ₄	Fe ₄ Si ₃ O ₁₀ 4.024 Fe ₂ SiO ₄ 0.5035 Fe ₃ SiO ₅	Fe ₂ SiO ₄ 1.757 Fe ₃ SiO ₅ 0.6807 Fe ₄ SiO ₆
1.000	1.183	1.600	2.016
CaSiO ₃	Ca ₄ Si ₃ O ₁₀	Ca ₂ SiO ₄	
1.000	3.483	1.482	

FeSiO ₃ 1.00	Fe ₄ Si ₃ O ₄ 3.543	Fe ₂ SiO ₄ 1.543	Fe ₃ SiO ₅ 2.087	Fe ₄ SiO ₆ 2.630
	,			

III. BASES

Radical	Mol. wt.	Log.
MgO	40.36	1.60595
CaO	56.1	1.74896
Na ₂ O	$62.\overline{1}$	1.79309
MnO	71.0	1.85126
FeO	71.9	1.85673
K ₂ O	94.3	1.97451
SrO	103.6	2.01536
ZnO	106.6	2.02776
Cu ₂ O	143.2	2.15594
BaO	153.4	2.18583
PbO.	222.7	2.34772

Acids

Radical	Mol. wt.	Log.
Al ₂ O ₃	102.2	2.00945
B ₂ O ₂	70.0	$2.00945 \\ 1.84510$
P_2O_4	142.0	2.15229
SiO ₂	60.4	1.78104
TiO ₂	80.1	1.90363

IV. Composition of Type Slags (Calculated to a 90 per cent. total)

Compound	BiO ₂	FeO	CaO
FeO·SiO ₂ . 4(FeO·SiO ₂) + CaO·SiO ₂ . 3(FeO·SiO ₂) + CaO·SiO ₂ . 2(FeO·SiO ₂) + CaO·SiO ₂ . 3(FeO·SiO ₂) + 2(CaO·SiO ₂). FeO·SiO ₃ + CaO·SiO ₂ . 2(FeO·SiO) + 3(CaO·SiO ₂). FeO·SiO ₂ + 2(CaO·SiO ₂). FeO·SiO ₃ + 3(CaO·SiO ₂). FeO·SiO ₄ + 4(CaO·SiO ₂). CaO·SiO ₂ . (FeO) ₄ (SiO ₂) ₃ . 4(FeO) ₄ (SiO ₂) ₃ . 4(FeO) ₄ (SiO ₂) ₃ + CaO·SiO ₂ . (FeO) ₄ (SiO ₂) ₃ + CaO·SiO ₂ . (FeO) ₄ (SiO ₂) ₃ + CaO·SiO ₂ . (FeO) ₄ (SiO ₂) ₃ + 4CaO·SiO ₃ . (FeO) ₄ (SiO ₂) ₃ + 4CaO·SiO ₃ . (FeO) ₄ (SiO ₂) ₃ + 4CaO·SiO ₃ . (FeO) ₄ (SiO ₂) ₃ + 4CaO·SiO ₃ . (FeO) ₃ SiO ₂ . 4(FeO) ₃ SiO ₂ . 4(FeO) ₃ SiO ₂ + CaO·SiO ₂ . 3(FeO) ₃ SiO ₂ + CaO·SiO ₂ . (FeO) ₃ SiO ₂ + CaO·SiO ₃ . (FeO) ₃ SiO ₂ + CaO·SiO ₃ . (FeO) ₃ SiO ₃ + CaO·SiO ₃ .	41.1 42.1 42.4 42.8 43.2 43.6 44.7 45.2 45.4 46.7 34.8 35.5 36.4 37.2 38.1 40.9 46.7 26.6 29.1 32.2 33.9 35.8 40.6	48.9 40.1 37.8 34.0 30.8 26.1 21.1 17.7 13.4 10.8 	7.8 9.8 13.2 16.0 20.3 24.7 27.6 31.4 33.8 43.3 2.5 6.2 8.6 11.7 21.6 43.3 5.4 11.9 15.7 20.0 30.1 43.3
	SiO ₃	FeO ₂	CaO
(FeO) ₂ SiO ₂ + (CaO) ₄ (SiO ₂) ₂ 3(FeO) ₂ SiO ₂ + 2(CaO) ₄ (SiO ₂) ₃ (FeO) ₂ SiO ₂ + (CaO) ₄ (SiO ₃) ₃ 2(FeO) ₂ SiO ₂ + 3(CaO) ₄ (SiO ₂) ₃ (FeO) ₃ SiO ₂ + 4(CaO) ₄ (SiO ₂) ₃ (CaO) ₄ (SiO ₂) ₃ (FeO) ₃ SiO ₂ 4(FeO) ₃ SiO ₂ + (CaO) ₂ SiO ₃ 2(FeO) ₂ SiO ₂ + (CaO) ₂ SiO ₄ 2(FeO) ₃ SiO ₂ + (CaO) ₂ SiO ₄ 3(FeO) ₃ SiO ₂ + 2(CaO) ₂ SiO ₃ (FeO) ₃ SiO ₂ + 3(CaO) ₃ SiO ₃ (FeO) ₃ SiO ₄ + 2(CaO) ₃ SiO ₂ (FeO) ₃ SiO ₄ + 3(CaO) ₃ SiO ₂ (FeO) ₃ SiO ₄ + 3(CaO) ₃ SiO ₂ (FeO) ₄ SiO ₄ + 4(CaO) ₄ SiO ₄ (FeO) ₄ SiO ₄ + 4(CaO) ₄ SiO ₄	26.6 31.1 34.3 35.7 36.8 38.7 40.2 26.6 27.5 27.7 28.1 28.9 29.6 30.1 30.4 31.5	63.4 42.4 27.3 21.2 15.9 7.1 63.4 52.3 49.4 44.5 40.5 34.3 27.9 23.6 17.9 14.4	16.5 28 4 33.1 37.3 44 2 49.8 10.2 12.9 17.4 21.1 26.8 32.7 36.8 42.0 45.2 58.5

	SiO ₁	FeO	CaO
(FeO)4(SiO ₂)4	34.8	55.2	
4(FeO) ₄ (SiO ₂) ₃ + (CaO) ₄ (SiO ₂) ₃ 3(FeO) ₄ (SiO ₂) ₃ + (CaO) ₄ (SiO ₃) ₃	35.7 36.0	45.4 42.9	8.9 11.1
$2(FeO)_4(SiO_2)_1 + (CaO)_4(SiO_2)_2 \dots$	36.6	38.4	15.0
$3(FeO)_4(SiO_2)_4 + 2(CaO)_4(SiO_2)_3$ $(FeO)_4(SiO_2)_3 + (CaO)_4(SiO_2)_3$	36.7 37.3	35.1 29.6	18.2 23.1
$2(\text{FeO})_4(\text{SiO}_2)_8 + 3(\text{CaO})_4(\text{SiO}_2)_2 \dots$ $(\text{FeO})_4(\text{SiO}_2)_1 + 2(\text{CaO})_4(\text{SiO}_2)_2 \dots$	37.9 38.2	24.0 20.2	28.1 31.6
$(\text{FeO})_4(\text{SiO}_2)_4 + 3(\text{CaO})_4(\text{SiO}_2)_4 \dots$	38 7	15.4	35.9
$(FeO)_4(SiO_2)_2 + 4(CaO)_4(SiO_2)_3$ $(CaO)_4(SiO_2)_1$	$\frac{39.0}{40.2}$	12.4	38 6 49.8

Formation Temperature of Some Pure Ferrous Silicates

```
4FeO, SiO<sub>2</sub> = 82.8 % FeO, 17.2 % SiO<sub>3</sub> = 1280°C.1

3FeO, 2SiO<sub>3</sub> = 64.3 % FeO, 35.7 % SiO<sub>4</sub> = 1140°C.1

FeO, SiO<sub>4</sub> = 54.55 % FeO, 45.45 % SiO<sub>2</sub> = 1110°C.1

2CaO, SiO<sub>2</sub> = 65.0 % CaO, 35.0 % SiO<sub>2</sub> = 1570°C.2

CaO, SiO<sub>3</sub> = 48.2 % CaO, 51.8 % SiO<sub>3</sub> = 1540°C.9

3CaO, SiO<sub>3</sub> = 58.2 % CaO, 41.8 % SiO<sub>2</sub> = dissociates at 1475°C.3

3CaO, SiO<sub>2</sub> = 73.6 % CaO, 26.4 % SiO<sub>2</sub> = dissociates at 1900°, before
                                                                                                                                                                                                                                                                                                                                   melting*
4CaO, 3SiO_1 = 37.0 \% CaO, 63.0 \% SiO_2 = 1436°C.<sup>3</sup> 4CaO, <math>3SiO_2 = 54.5 \% CaO, 45.5 \% SiO_2 = 1455°C.<sup>3</sup>
```

FORMATION AND MELTING TEMPERATURES OF SILICATES

Description	SiO ₁	Al ₂ O ₂	41.	posi- on	MgO	BaO	MnO	For-	Fue-
			FeO	CaO				mation temp.	ing temp.
Iron slag ⁴ Lead slag ⁴ Lead slag ⁶	50.0 43.9 36 0 31.47 83 0 40.80	7 0	4.5 40.0 45.68	30.0 31.4 4 0 22.85 19.74	10.2	7.5	0.3	1392 1450 1220 1190 1273 1160	1208 1250 1160

¹ Trans. A. I. M. B., Vol. 29. ² F. T. HAVARD, "Furnaces and Refractories." ³ RANKIN and WRIGHT, Am. Journ. Sci., January, 1915. ⁴ From HAVARD, "Furnaces and Refractories." ⁵ See also p. 27

Total

99.9

		10 100 10		•	•	•	-	282	9000
	P ₂ O ₅	0.15 14.78 21.90	ū	:	:	:	4	0.00	1.05
	NaKO	9 - 0144004	ಭಾ		:	* * * * * * * * * * * * * * * * * * * *	:	0.18	2 08
	Z		ZnO	:	:		:	86 T	
	Ca.B	25.25	NeaO	1.7	:	:	:	4.05	
			MgO	0.5	1 0	0.37	1.6	0 87 1.87 4 40	0.74
OCTS	MEO	2 7 44 4 0 09 3 42 8 4 00 5 4 00 14 0	CaO	7.9	3.6	1Q	4.5	23.40 33.1 21.81	620.00
PRODUCTS	MnO	1.62 15.74 31.89 2.05	Alson	4.00	9.0	9.00	147 40	7.83 4.43 16.63	7.24
NACE	FegOs	0.76 3.56 1.00	MnO	Trace	11.1	5.64	1.5	0.28	
MISCELLANEOUS FURNACE	CaO	32.82 49.39 11.84 26.0 0.6 1.3	FeO	26.2	20.3	20.75	48.2	7.47 4.35 3.46	41.15 65 62 31.9
ANEOD	AI ₃ O ₁	15.13 3.45 3.45 16.0 16.0	SpO	1.00	7.5	9.36	5.40		
BCELL	SiO,	34.48 48 19 112.30 47.255 40 0 228 6 230.5	(g)	00		-			
Mı	 		WOI	1.3		24.03	3,0	F-2.09	
			SiO ₁	39 4	40.0	24.08	27.5	57.43 53.83 46.70	200 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
		from blast furnace elage And open hearth elage Bessenter converter slage Busic converter slage Busic converter slage Charcoal from furnace slage Arizona converter slage Arizona converter slage Arizona converter slage Arizona converter slage		Tin slag (glass), Cornish reverberatory	boratory' The Debenese formalism	Bigeling	IN Start, Security and Business	Manufeld copper sing. (vr. 57.43 Manufeld copper sing. 53.83 Manufeld copper sing. 53.83	Cr. 3.342). Oker (subsilicate). Arisona copper precioes 35.6

0.28 0.35 0.63 0.63 0.63 8.50 8.50 8.50 8.50 8.50 8.50 8.50 8.50	4.43 0 47 1 00 99 8	3.44 2.40 0 91	10.1 0 61 35 2	PrO ₅ 14.81 4 46 0 69	1.09 0 22	* Private notes. Metallurgues Calculations."
6961 69 11	:	2.5	0.51	1.11	3 14	- 1
წო⊬ ტ წ4 იიოფე	#	4.5	1.67	4.45 4.75 7.81 14.70	50 ¹ 10.95 05 17.50	ICHARDB'
15.3 5.3 5.3 5.3 5.3 5.3	8.90	1 76 10.0 10.08	¥. 19	7.81	15 50 27 06	RICE STORY
	:	8 : : : 0 : : :		0.92	: :	r Smell
23. 23. 24. 24. 25. 24. 25. 25. 25. 25. 26. 27. 26. 27. 26. 27. 26. 27. 26. 27. 26. 27. 27. 27. 27. 27. 27. 27. 27. 27. 27	Fe 50,40	Fe 55.83 43 0 7 9 03	3 75 10.54 40 0	28.37	9.24	"Modern Copper Smelting.
		88	5.7 Pb0	2.87	1.10	PETERS, "Mo
400 00 5- 41 41 10 - 00		70 Ni = 4.85 72 Ni = 4.85	2022	09.	.35	
Arisons copper practice. 35.4 Arisons copper practice. 39.8 Arisons copper practice. 40.6 E.Arisons copper practice. 43.7 F.New Jersey cupols practice. 28.4 New Jersey matting furnace 33.43 Arizons converter slage. 2.14 Settler sow. 2.14	Ining, Parrott.* Conner converter alac. scid	Nickel slag, ore smelting ¹¹ , 38 0 Ni = Nickel slag, ore smelting ¹¹ , 2 11 Ni = Zinc retort residue.	furnacet. Copper refinery slag	and reduction Practing roading and reduction 37.50	West, U. S. A ² Middle West, U. S. A ² Middle West, U. S. A ² Middle	1 HENRY LOUIS, "Tin."

Schwarl's "Handbook of Metallurgy"

• Private notes, Some of these Arrona slags are interesting because of their high alumina content

• Private notes. A wonderfully clean slag, almost snow white in color,

• Private notes. A wonderfully clean slag, almost snow white in color,

• Private notes. A wonderfully clean slag, almost snow white in color.

• Private notes. A wonderfully clean slag, almost snow white in color.

Poured slag, ore aming Poured slag, quartz lining 19 60 per cent matte being produced, practice given by Schristic the blast-furnace slag, slowerstein operations Formatance, a year's results in Canadian bractice give the following average for the blast-furnace slag. SiOr, 35 37; Fe. 3 + 69; CaO. 5, MgO. 5 10, Al-Or, 8; S. 0 82; Cu. 2 4; Ni. 3 5 per cent The corresponding matte, for a yearly average carried. Ni 19 33, Cu, 13 23 per cent The succeeding year gave. SiOy, 34 89, Fe. 35 06, B. 1.01, Cu, 2.0, Ni, 3 9; with corresponding matter Ni, 20 55, Cu, 10 7 per cent. The year following thus showed. SiOy, 33 90; Fe, 39 59; S. 1.31, Cu, 1.8, Ni, 3.9; with corresponding matter Ni, 20 92, and Cu, 8.57

Treical Furnace Products

	Ö	2	14 0	Ä	రి	8	44	γ	Ψn	20	Bi	ZD
Speiss—Schmöllnitat Speiss—Neuschlt, Black copper Mansfeld Converter copper Monean Converter copper—Australian Converter copper—Australian Converter copper Western U. S., Lead from blast furnace—Freibergt 0	112 99 96 89 99 98 89 99 28 99 28 99 11 18	0.09 0.09 1.93 1.864 0.684 0.262 tr. 95.088	12.63 35.41 0.0068 0.00123 0.007	0.100 0.100 0.100 0.014	000 848 800	0.171 0.171 0.864 0.012 0.012 0.958	7.42 6.10 0.085 0.509 tr.	000-0000 888888 8444 1444	0.00000	0.005 0.005 0.005 0.005	1.26 None 0.068 0.004 0.019	000

1 SCENABBL, "Handbook of Metallurgy,"

TOTAL HEAT IN CALORIES PER KG. OF MELTED SLAG (After AKERMAN)

Calories	Per cent., SiO ₂	Per cent., CaO	Per . cent., Al ₂ O ₃	Calories	Per cent., SiO ₂	Per cent., CaO	Per cent., Al ₂ O ₃
347 {	59 39 63 58	36 42 35 35	5 19 2 7 5	360 {	31 46 58 58	37 37 32 27	32 17 10 15
350	58 53 41 38	37 37 42 47	5 10 17 15	380	62 38 25 44	37 52 34 33	1 10 41 23
	39 37 66 59	43 40 32 38	19 23 2 3 10	400	60 65 41 37	20 35 52 53	20 0 7 10
360 {	48 40 34	42 48 48	10 12 18		21 43	32 30	47 27

TYPICAL LEAD SLAGS¹

	SiO ₂	Fe(Mn)O	Ca(Ba, Mg)O	Total
Eilers	28	50	12	90
Eilers	30	40	20	90
Livingstone	30	36	20	86
Iles	32	33	23	88
Schneider	33	33	$\overline{24}$	90
Page	33	36	$\overline{16}$	85
Hahn	34	50	$\overline{12}$	96
Raht	35	27	28	90
Hahn	36	40	20	96
Murray	40	34	26	100
Hixon	34	33	$\frac{23}{23}$	90
Hixor	33.4	34.1	$\frac{20}{21}$	88.5
Hixon	30	40	$\frac{20}{20}$	90

Temperatures of Metallurgical Operations

Copper blast-furnace smelting:	
Furnace running fast	. 1260°C.¹
Normal smelting	1215°C.1
Slow smelting, lower limit	1130°C.1
Pyritic smelting 1240	°-1350°C.1

¹ Hofman, "Metallurgy of Lead," and Hixon's "Lead Smelting and Copper Converting."

Copper converters: Matte introduced
Temperature of escaping gas at finish
Lead blast-furnace work: On two-fifths slag, Fe, 30 per cent.; CaO, 12 per cent.; Al ₂ O ₃ , 8 per cent.; SiO ₂ , 31 per cent., Zn, 10 per cent.; was 1126°C. On half slag, 1134°C. On three-fifths slag, Fe, 30.5 - 31 per cent.; CaO, 15 - 14.5 per cent.; Al ₂ O ₃ , 6.4 - 6.6 per cent.; SiO ₂ , 34 - 32 per cent.; Zn, 5.8 per cent.; MgO, 1.3 per cent., MnO, 3.7 - 3.8 per cent., 1170° - 1149°C. The temperature change seems to be about 9°C. per cent. of silica up or down, from the above figures.
Reverberatory smelting—copper matting: Slag temperature
Reverberatory roasting—leady mattes: 1215°C. at fire box to 505°C. at flue end.
Reverberatory smelting flue: 1300°C. at furnace; 1217° at 14 ft. from furnace; 1112° at 27 ft.; 1097° at 41 ft.; 1045° at 54 ft.; 911° at 67 ft.; 807° at 80 ft.; 767° at 94 ft.; 727° at 107 ft.; 642° at 120 ft. (foot of stack).
Iron ²
Blast furnace at tuyères

¹ Rounded averages (to nearest 5°C.) of figures given by G. H. CLEVENGES Metallurgical and Chemical Engineering, August, 1913. Other figures not averaged.

² Stowe-Füller Co.'s catalog.

Medium-hard steel at tapping	1600
Gas leaving producers	700
Gas leaving regenerators	1200
Air leaving regenerators	1100
Waste gas at stack	300
Medium steel ready to roll	1050
Glass pots working	1050
Glass pots refining	1325
Tanks for casting glass	1325
Crucible-steel furnace	1300
Cement rotary clinkering kiln	1684
Ingot being rolled	1065
Heating furnace	1150

Modern Copper Blast Furnaces1

•	Dimen- sions at tuyère, in.	and size	Center of tuyère to feed floor ft. in.	Height of smelting column, ft.	Blast pressure, os.	Approximate capacity, tons
Cananea, Mexico	56×1044 48×210	150-4 36-434	19 10 414		40 16	3000 280
Garfield, Utah Mammoth, Calif Steptoe, Nev	48×240 50×180 42×240	34-434 48-4	13 0	10 9	24 42 40	360 400 300-500
Cerro de Pasco, Peru. Mason Valley, Nev		28-4 50-4 40-5	12 1 14 6	12	24 42 28-32	300 720
	50×204 50×240		14 0	14 14		400 550
	50×240 42×210 42×360			12 8		550 350 650
	42×264 42×420			808		460 700
Grand Forks, B. C. {	50×420 44×266½ 48×260			8 12 12	• • • • •	875 500 550
Great Falls, Mont	84×180 42×216		22 31/2			
Copper Queen, Ariz.	42×240			• • • • • •		
United Verde. Ariz Anyox, B. C B. C. Copper Co., B. C.	48 × 330 50 × 360 51 × 360	72-314		12 12		750 850
·	51 × 360 51 × 240 42 × 120	72-314		12 12 6		550 200
- J 00 00 pp. 1 - 1 0 1 1 1 1	48×160			6		300

¹ From Gowland's "Metallurgy of the Non-ferrous Metals," p. 83, and Bull. 209, Canad. Dept. of Mines.

² The Anaconda furnace is the largest yet constructed.

Blower Capacity

Iron Cupola Work.—500 cu. ft. of air per minute is required to melt 1 ton of pig iron per hour.1

Rotary blowers seem to require 5 hp. for every 1000 cu. ft. of

air discharged at 1 lb. pressure.2

Copper Blast Furnaces.—At the Tennessee Copper Co. 1000 cu. ft. per minute per linear foot of furnace is the rule (56 imes 270in. furnace). At Mt. Lyell 20,000 cu. ft. at 64 oz. pressure is used per minute in a 54×210 -in. furnace. At Great Falls, Mont., a furnace 84×180 in. at the tuyères receives 17,000 cu. ft. of air per minute. The Sasco, Ariz., smeltery used 13,000 cu. ft. per minute at 24 oz. pressure for a 43 × 192-in. furnace. Cananea used 12,000 cu. ft. per minute at 16 oz. pressure for a 48 \times 210-in. furnace.

Converters.—The Copper Queen works figures that it requires 85,800 cu. ft. of blast to convert 1 ton of matte to blister

copper.

OPERATIONS AT THE BRITISH COLUMBIA COPPER Co.'s SMELTERY⁸

Blast furnaces.—The blast furnace building is 150 ft. long by 60 ft. wide and contains three water-jacketed blast furnaces placed end to end, with space between them for the minor axis of a 10 by 18-ft. oval settler. The two outside furnaces, Nos. 1 and 3, are each 51 by 360 in., while the middle one, or No. 2, is 51 by 240 in. in area at the tuyères. The vertical distance from the center of tuyeres to the feed floor is 16 ft., and to the sole plate 37 in., the other furnace dimensions being as follows:

		0
_	30-ft. Furnace	20-ft. Furnace
Hearth area, sq. ft	127.5	85
Center tuyères to tapping floor		5 ft. 3 in.
Height of bottom jackets	. 9 ft. 0 in.	9 ft. 3 in.
Width of side jackets	. 3 ft. 4 in.	3 ft. 4 in.
Width of end jackets, bottom		3 ft. 8 in.
Width of end jackets, bottom	. 6 ft. 2 in.	6 ft. 2 in.
Number of tuyères		4 8
Diameter of tuyères		ed to 31/4 in.
Area of tuyères		
Tuyère area per square foot of hearth		•
area		$7.09\mathrm{sg.in}$
Center line to center line tuyères		
Water space in jacket, 4 in.; plate		
outside, 3/8 in.		

A Résumé of Furnace Operating Data, B. C. Copper Co.

Tons smelted per day, 2250.0; tons smelted per square foot of hearth area, average, 6.62; tons smelted per square foot of hearth area, maximum, 8.70; tons smelted per man per day,

¹ Hofman, "General Metallurgy," p. 777. ² Ibid., p. 771.

From a paper by F. K. BRUNTON, Trans. A. I. M. E., 1915.

35.70; Cu, on charge, per cent., 0.8 to 1.2; Cu. in matte, per cent., 30.0 to 45.0; Cu in slag, per cent., 0.22 to 0.27; S on charge, per cent., 2.00; S burnt off, per cent., 85.00 to 90.00; coke used on charge, per cent., 12.00 to 14.00; coke ash, per cent., 20.00 to 28.00; blast, cubic feet per minute, 25,000; blast, temperature, atmospheric; cooling water for jackets, gallons per minute, 2500; men per 8-hour shift, 21.0; matte, per cent. of total charge, 1.65; matte, specific gravity, 5 to 0; slag, per cent., SiO₂, 38 to 45; Fe, 13 to 20; CaO, 20 to 26; Al₂O₃, 6 to 9; specific gravity, 3 to 3.2.

Kind of labor	Number of men	Wages per shift	Total wages per shift
Shift bosses	. 1	\$5.25	\$5.25
Furnace men	$\ddot{3}$	4.00	12.00
Furnace helpers	3	3.00	9.00
Slag motorman	ī	3.40	3.40
Slag switchman	$\bar{1}$	3.00	3.00
Charge motormen	$ar{3}$	3.15	9.45
Head loaders	3	3.15	9.45
Second loaders	3	3.00	9.00
Feeders	ĭ	4.00	4.00
Binman	ī	2.75	2.75
Power house	ī	3.40	3.40
Total	21		\$70.70

Costs of Copper Smelting—British Columbia Copper Co.

The following costs do not include overhead expenses, depreciation or insurance:

procession or madraneo.	
Cost per ton of smelting ore to matte ¹	\$ 1.18
Cost per pound of copper of converting matte to blister	0.0048
Cost per ton of copper of converting matte to blister	9.60
Cost per ton of smelting ore to blister copper	1.23
Cost per ton of copper to produce blister copper	0.105
Cost of coke per ton of ore smelted to matte	0.851
Cost of flux per ton of ore smelted to matte	0.114
Cost of labor per ton of ore smelted to matte	0.15
Cost of power per ton of ore smelted to matte	0.033
Cost of supplies per ton of ore smelted to matte	0.03
•	\$1.178
Cost of coke per ton f.o.b. smelter bins	\$6.00
Cost of flux per ton f.o.b. smelter bins	2.75
Cost of power per kilowatt-hour	0.0065

¹ Note.—The furnaces were slowed up with an excess of silica on the charge because of shortage of ore, hence the higher cost per ton of ore smelted to matte. They smelted only 6.55 tons per square foot of hearth area against 6.66 tons per square foot when the cost smelting was \$1.084.

Briquette mill handled 1057 cars of blast-furnace flue dust and made 398 tons of briquettes.

Briquette cost \$0.945 per ton for labor.

Distribution of smeltery payroll for same month and cost of labor per ton of ore smelted:

·	Payroll distribution	Cost of labor per ton of ore smelted
Sample mill	\$ 318.05	\$0.00462
Bins	729.35	0.01060
Briquette	376.65	0.00546
Furnaces	6,508.35	0.0958
Slag disposal	1,413.65	0.0206
Linings	615.60	0.0078
Converters	1,016.85	0.0147
Crane	277.25	0.00403
Water system	224.65	0.00326
General surface	430.15	0.00624
Power house	585.60	0.00850
Total	\$12,496.15	\$0.18161

JACKET WATER REQUIRED¹

Hearth area, aquare feet	Water per hour, blowing in or out, gallons	Water per hour, normal running, gallons
3	900	460
5	1200	600
7	1450	950
9.5	2200	1100
12.5	3000	1300
18	4000	1500
24	5000	1800
30	6000	2000
36	7000	2200

Analyses of Copper Blast Furnace Gases

	0	СО	CO ₂	SO ₂	SO.	N
Morenci, Ariz Globe, Ariz	17.2	2.15 3.2	10.9	$2.5 \\ 3.5$		
Copper Queen	10.0	$(\mathrm{H_2O}\atop 3.5)$	6.49	1.27	0.086	78.1
Tennessee ²			3.5	3.50	Tr.	

¹ Peters's "Modern Copper Smelting."

² As delivered to sulphuric acid chambers. According to ROBERT STICHT'S data, all of the above results showing free oxygen are open to doubt, as he believes that oxygen can only be present in the free state in copper furnace gases when extraneous air is drawn into the testing apparatus via the charge doors.

FEFFLING PRACTICE AT IMPORTANT NORTH AMERICAN SMELTING WORKS

Works at	Copper Cliff, Ont.	Great Falls, Mont.	Anaconda, Mont.	Toosle, Utah	Garfald, Utah	McGill, Nev.	Humboldt,
Size of reverberatory fur-	19×112 ft.	16 ft. 9 in.	19×110 ft.	19×102 ft.	20 ft. 4 in. × 123	18 ft. 9 in. X	19×60 ft.
Kind of material smelted. Caloines,	Calcines, 80%	Rossted	Rossted conc.	Low-grade	Rossted Conc. Low-grade Rossted conc. Rossted conc.	Roasted conc	Ronsted cone.
	five dust, 20%.	five dust.			sand.	verter secondaries and	raw cone., limerock and
Present fettling ma-	Green ore and calcines.	Crushed	Crushed Strushedsand-Siliceous	Siliceous ores		Siliceous sul-	90
How fettled	Dropped	Thrown in	Thrown in.e		ped through	or mill slimes. Thrown in.	slimes. Thrown in.s
Frequency of fettling	Continually	u t	Monthly.	Every 2 to 4 bours.	to 4 About every 5 Daily.		Twice daily.
Tons of fettling used per furnsce day	300@	68.ym	1	- s-10	ю	27	About 5% of
Tons smelted exclusive of fettling.		2002	27.5	300	401	612	total charge.
Total tons smeited.	Pulverised cost	203 G88.c	276 Coal e	210 Coal,	200 C	O SS PHI	1012 141
SiOs in alag Any trouble with silice-	ñ	37.9% Occasion-	39 68% No.	100	43.5% Some floaters but		No.
How often are side walls Not since start-	Not since start-		ín	8 Eight or nine	e trouble.	Semiannually Not	Not yet
Where is greatest wear	Roof.	At bridge.	Matte line near firebox	Arch and sides 20 to 30 ft. from bridge.	Arch and sides In the 40 ft. near- In the 50 ft. Bridge 20 to 30 ft. eat the firing end. nearest the side from bridge.	In the 50 ft. nesrest the firing end.	
							25 ft. from bridge,

•	Continued
	WORKS.
	SMELTING
	AMERICAN !
	North.
	IMPORTANT
	AT
	PRACTICE
	FETTLING

	THE CHILD	7797017	Name of the last o			
Works at	Clifton, Ariz.	Douglas, Aris., C. & A. Wks.	Douglas, Ariz., C. Q. Wks.	Hayden, Aris.	El Paso, Texas	Cananea, Mex.
Size of reverberatory furnace	. 2	ft.	ft. Aue	19×112 ft. Roasted conc. and limerock.	19×100 ft. Roasted conc. and flue dust.	1915×100 ft. Rossted conc. and flue dust.
Present fettling materials	sinceous copper ores, and slag and matte.	Copper ores, carrying S, 1.7 to 23.8 %; SiO ₃ , 29.2 to	Copper Queen gulphur-bear- ing ores.m	Conc. and converter slag.	and Siliceous ore.	High-grade conc. and sili- ceous ore.
How fettled	Dropped through roof.	Dropped through roof.	DroppedDroppedFed through roof. through roof. spe	through cial side enings.	Thrown in, except at bridge above which are fettling	Dropped through roof.
Frequency of fettling. Tons of fettling used per furnace day. Total tons smelted. Fuel. Fuel. Fuel ratio! SiOs in slag. Any trouble with siliceous floaters. How often are side walls repaired.		Practically continuously 55 55 290 3456 Oil. 0.8 bbl.k	Practically continuously 75 75 300 0il. 0.9 bbl. 34.8% No. Eight to nine months.		ar iii : iii iii ar ar ar ar ar ar ar ar ar ar ar ar ar	
where is greatest wear in lurnade	Under second charge hole, 20 ft. from burners.	Charge hole, from the 20 ft. from bridge. 20 ft. from bridge wall. burners.	At hring end.		In hrst 30 it. from bridge.	First 40 ft. of arch and 20 ft. of side walls.

	Ö	Composition of	ition o		berato	reverberatory alaga	6.	ပိ	Composition of fettling materials	ion of	fettlir	8 m 3	terial			-	Í
Situation of works	Au, or.	A.E.	ų β _k	SiO ₄ ,	FeO,	CaO,	AlsOs	Au, os.	Ag, 05.	Çu,	SiOs,	40%	N.	00 18%	ខ្លុំ	% p	, %
Copper Ciff, Ont mil mil 0.50 Great Falls, Mont. 0.001 0.1 0.45 Anaconds, Mont 0.0006 0.19 0.39 Tooele, Utah 0.001 0.035 0.35 McGill, Nev 0.003 0.008 0.345 Humboldt, Aris 0.33	0.000 0.000 0.000 0.003	74.00.19 0.19 0.008 0.008	0.50 0.50 0.00 0.00 0.00 0.00 0.00 0.00	38 1 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	124444688 3 40080008 4	5. 1c	00 00 h	20 00 00 00 00 00 00 00 00 00 00 00 00 0	20.00 7.00 0.07	5.50° 0.20° 3.28° 7.30° 9.50°	2000 100 100 100 100 100 100 100 100 100		200 - 100 -	40.0000 H	0 . 6 . 64	Siliceous	1 5 0.4 ores.
Douglas, Aris., C. 0.5 bouglas, Aris., C.Q. 0.10 0.487 Hayden, Aris. 0.10 0.487 El Paso, Tex 0.12 0.48	, C.Q. 0.10 0.487	0.10 0.48; mil 0.12 0.48	0.487	34.8	46.0	1.9	8.6 8.6 10.4	0.038 0.013 0.013 0.013	9899	24 24 24 24 24 24 24 24 24 24 24 24 24 2	8858888558 8858888559	-4000000ng	700000-140 	PER 400008	8-854-896 8-850-650	Sulphide ore. Oxide ore. Siliceous ore. Concentrates. Converter slag. Concontrates.	Sulphide ore. Oxide ore. Siliceous ore. Concentrates. onverter slag.
o Ou-Ni.	p Repo	rted &	Fe: c	Sonvert	od be	reo to	p Reported as Fe: converted to FeO for comparison.	arison.	-	CaO-MgO	Ģ.						

Fettling Practice at North American Smelting Works¹

The fettling of reverberatory furnaces has undergone marked change in the last 8 or 10 years. This is well illustrated in the table on the preceding pages, which has been compiled from replies received from officials of the leading smelting works in North America that use reverberatory furnaces. presents in concise form much interesting data regarding the reverberatory furnaces of the country, but the most striking feature is the diversity in fettling practice between the older and Most of the newer works fettle the furnaces newer plants. through the roof, while the older plants throw the fettling in through the side doors. The older works still use for the most part quartz or other high-silica material, and naturally use this fettling as sparingly as possible. The newer plants, on the other hand, drop almost any material on the sidewalls and in large quantities, the idea being that the sidewalls will be protected if a sufficient amount of cold materials be dropped thereon. should be remarked, however, that most of the plants that fettle through the roof use ores or products containing sulphur. some carrying the revolution so far as to use raw concentrates. or converter slag or matte cleanings—materials that a few years ago would have seemed absolutely heretical.

When the fettling was dropped through the roof on the side walls in great quantities, some of it naturally floated out into the furnace, and after some experimentation it was found that raw ore, floating off with the slag, during skimming, was increasing the metal loss; this led to the use of siliceous ores containing copper as sulphide, in which form it would be readily removed by the heat of the furnace. This practice has been carried still farther by the use of ores carrying as much as 15 per cent. sulphur as at Douglas, and also by the use of raw concentrates, as at Cananea and elsewhere, confirming the hypothesis that a large quantity of cold materials was what was

needed to protect the side walls.

It should be borne in mind in consulting the table that much of the data is approximate and subject to the personal equation of the official answering the series of questions submitted. example, in the matter of tonnage figures, it may readily be that one official is reporting the tonnage of his furnace under the best normal operating conditions, whereas another may have given the average tonnage actually smelted in a given month, thus including interruptions or accidents that invariably reduce the actual tonnage smelted below the average of the furnace under the best conditions. Hence the tonnages given should be merely regarded as approximate. In several instances officials went to the trouble to point out that molten converter slag was not included in tonnage reported. This is what would normally be expected, but it is not clear whether this is the case in every instance. The answers to the various questions have been inserted in the table in the original phraseology of the reporting

¹ Eng. and Min. Journ., Oct. 17, 1914.

official wherever that was consistent with a proper interpretation by comparison with other data submitted. The subsidiary table showing the analyses of the slags and of the fettling materials will be of interest, and some of the other incidental information will attract attention, particularly that touching on the practice in Montana, where some important changes are taking place.

Coal-dust Firing of Reverberatories¹

A general discussion by C. J. Gadd of the principles of coaldust firing appears in the Journal of the Franklin Institute for 1916, p. 323. The main points are as follows: Powdered coal, used as a fuel in metallurgical furnaces, should be high in volatile matter and low in ash, and should not contain over 0.75 per cent. H₂O. At least 95 per cent. of the coal should pass through a sieve with 100 meshes to the linear inch, and over 83 per cent. through a 200-mesh sieve; it must be delivered to the furnace "in a thoroughly atomized state," and combustion must be completed while the coal is in suspension. Delivery to the furnace must be uniformly controlled, and the personal equation reduced to a minimum. While anthracite, lignite and coke breeze may be used, the most desirable fuel is bituminous coal, high in volatile matter and low in S and ash. The coarse coal should approximate the following analyses:

	For heating and puddling furnaces, per cent.	For open- hearth furnaces, per cent.
Volatile matter not under		36.00
Fixed C not under		52.00
H ₂ O not over	1.25	1.25
Ash not over		6.00
S not over		1.00

Powdered coal should be handled in bulk; aerial propulsion and transfer in the form of dust clouds should be avoided on account of the danger of accidental ignition. Powdered coal, stored for any length of time, tends to fire, pack, and collect moisture. Spontaneous combustion invariably occurs within 6 days with a moisture content of approximately 0.75 per cent. and a S content of 1.0 per cent., and may occur within 24 hours if the H₂O content exceeds 1.0 per cent., and the S content be 4 to 5 per cent. The apparatus for crushing, drying, pulverizing, feeding, and burning the coal is described in detail, as are various types of metallurgical furnaces equipped for burning powdered coal. A low pressure burner gives a short flame, a high pressure burner a long flame. Powdered coal is more economical than oil or producer gas. The temperature is as high as that given by producer gas, and is maintained uniformly throughout the furnace. The high fuel consumption is offset

^{1&}quot;Bull." A. I. M. E., January, 1915.

by the generation of steam in the waste-heat plant, where each pound of coal, burned in the furnace, evaporates approximately 6.25 lb. of steam.

Experiments were made with this process at the plant of the Canadian Copper Co. at an early date, but were unsuccessful for some time.

It was finally adopted at Copper Cliff, however, designing furnaces especially to meet the requirements by eliminating right-angled bends in the flues and placing the skimming door at the side instead of the end. The waste-heat boiler was made a secondary consideration. The first smelting showed no difficulty with the fuel, and as improvements were gradually made the smelting became more efficient. In the first 3 months of 1914 the fuel ratio was 5, 5.65 and 6.77, respectively. method of feeding has been changed. At first it was done through hoppers near the fire end, but is now done almost entirely through pipes in the side walls. Coal dust is introduced through five pipes 5 in. in diameter. It is first dried and then ground so that about 95 per cent. passes a 100-mesh and 80 per cent. passes a The great advantage found in this method of 200-mesh screen. firing is the absence of breaks in the temperature curve due to grating or cleaning the hearth, and as a consequence a greatly

increased tonnage and fuel ratio.

At Anaconda coal-dust firing was tried in June, 1914, in a furnace 124 ft. by 21 ft. The method of charging was similar to that used at Copper Cliff. From the experience gained in this work, Mr. Bender lays down the following requisites for successful use of coal dust: (1) The coal should be dried before pulverizing, containing not more than 1 per cent. moisture; (2) fine pulverization affords increased area and higher thermal efficiency, 95 per cent. should pass a 100-mesh screen and 85 per cent. a 200-mesh; (3) the quantities of coal and air delivered to the furnace should be carefully controlled in order to secure complete combustion; (4) the coal should contain enough volatile combustible matter to give the required combustion; a standard for cement work is 30 per cent.; (5) the furnace should be properly designed and equipped, and (6) provision must be made for taking care of the ash. Based on past experience, some changes will be made in the new equipment for coal-dust reverberatory firing at Anaconda. The furnaces will be 144 ft. by 25 ft., with a flue area of 48 sq. ft. Matte will be tapped at the The skimming plate will be 12 in. higher than in other furnaces, the top of the plate being 24 in. above the tap hole. Recent records for a week at Anaconda indicate the efficiency of coal-dust firing; the average tonnage per day was 542.7, with a fuel ratio of 7.5.

Copper Losses in Slag.—An interesting series of articles by FRANK E. LATHE was published on this subject in the Engineering and Mining Journal of Aug. 7, 14 and 21, 1915, to which reference should be made for complete data. In general, however, the conclusions that he appears to consider well founded were that the loss of copper in the slag increases directly with

increasing matte tenor; that the loss in the slag decreases directly as increasing silica tenor, unless the matte be over 50 per cent. Cu; that probably 50 per cent. of the copper lost was as oxide and was due to overoxidation; that slags containing a large amount of metal with a high affinity for sulphur were likely to carry considerable copper (this would account for the effect Mn is sometimes supposed to have on a slag).

Reverberatory Practice

Some of the essentials of good ore-smelting reverberatory practice are thus summed up by R. E. H. Pomeroy.1

1. Careful preparation of the charge by adequate mixing of

all ingredients before charging.

2. Addition of enough lime rock, preferably coarse, to produce an active boiling in the furnace.

3. Maintaining a deep bath of molten matte to equalize and

distribute the heat over the whole of the hearth.

4. Frequent skimming so as to carry only a thin layer of slag over the matte bath.

5. Operating the furnace for the best smelting conditions, ignoring the waste-heat boilers as factors in the power supply.

Factors affecting the life of the furnace:

1. The furnace roof set high over the hottest portion of the

2. Frequent fettling to protect the side walls.

3. Frequent charging and active charge mixtures to avoid

floater and blanket formation requiring excessive firing.

The largest copper-ore-smelting reverberatory, so far as known, is the new one at Anaconda, with a 25×144 -ft. hearth. A furnace 178 ft. long has been built for settling reverberatory The largest copper-refining reverberatory is, so far as I know, 17 ft. \times 33 ft. 8 in., and has cast a charge of 550,000. lb. These figures are due to the courtesy of A. CLAYTON CLARK.

Electric Smelting of Copper Ores CLAUDE VATTIER'S LIVET EXPERIMENTS, 19032

	Analyses				
. •	Оге	Matte	Slag		
Cu	5.10	47.90	0.10		
§	4.13	22.96	0.57		
Fe	28.50	24.30	32.50		
Mn	7.64	1.40	8.23		
SiO ₂	23.70	0.80	27.20		
Al ₂ O ₃	4.00	0.50	5.20		
CO_2	4.31				
CaO	7.30		9.90		
MgO	0.33		0.39		
P	0.05		0.06		
	85.06	97.86	94.15		

_:..**z**____

Current, 4750 amp. at 119 volts.

One metric ton of ore smelted per hour.

Electrode consumption, 6.25 kg. per hour.

¹ Bull. A. I. M. E., February, 1915. ² J. W. RICHARD'S "Metallurgical Calculations," Vol. III.

According to D. A. Lyon and Robert M.Keeney, no copper ores are treated in the electric furnace in this country at the present time. It is reported, however, that in Norway trial smeltings of copper ores with an electric furnace of 1000 hp. and an estimated producing capacity of 2000 tons of copper per annum have been conducted at the Ilen Smelting Works, Trondhjem, and we understand that it is the intention to smelt copper ores regularly at this plant in the electric furnace.

Converter Output at Great Falls

In the article on the Old Dominion smelting works, at Globe, Ariz., in the Journal of June 6, 1914, attention is directed to the large daily output obtained in the Great Falls type converter used at this plant. The statement is made that this daily copper output, i.e., 60 tons is about double that reported last year by Messes. Wheeler and Krejci for shells of the same size at Great Falls, Montana.

COPPER OUTPUT OF CONVERTERS AT GREAT FALLS

Period	Tons copper produced per con- verter day	Per cent. cu. in. matte	Min. per ton of copper	Tons of iron and sulphur oxidized per converter day	Tons of ore used per converter day
Feb., 1914.	95.20	36.4	15.13	176	65.3
Mar., 1914.	89.27	33.8	16.13	186	71.4

While this is probably a record figure for upright shells, 12 ft. in diameter, it does not approximate the output obtained from the Class V or 20-ft. converters now in use at Great Falls. In the 20-ft. converters the average output of copper was over 95 tons per day in February, and nearly 90 tons in March when converting a 34 per cent. matte. In addition, from 25 to 30 tons of cold matte and cleanings are treated per converter day, and operations during the months cited were handicapped on account of reconstruction work; it is expected that the output will be increased when normal running conditions are restored. In the article "Great Falls Converter Practice," Messes. Wheeler and Krejci reported that the 20-ft. converter produced at the rate of 4.31 and 4.77 tons of copper per converter hour when in operation, or at the rate of 103.4 and 114.5 tons of copper per day, respectively; this was when converting a 38 to 39 per cent. matte.

¹ Bull. A. I. M. E., Feb., 1914.

AMERICAN CONVERTERS—OLD STYLE ACID LINED¹

Company, type	Out- side height, ft.	Out- side diam- eter, ft.	Blast pres- sure, lb. per sq. in.	Initial charge, lb.	Maxi- mum charge, lb.	D10W8		Number of
Parrot and M.O.P.Co.'s Anaconda Great Falls Stalmann Copper Queen.	8.5 10 13 8 7.25	5 6 7 5 5.67×8	11 13 16 10 5.5	2,500 7,000 10,000 3,000 4,000	17,000 22,000 9,000	12 10	16,000 22,000 26,000 17,000	16 18

Canadian Converter Practice²

Company	Туре	Stands	Shells	Dimensions
Canadian Copper Co.	Basic. Peirce-Smith			
	special	5	5	10' 0"×37' 2"
Mond Nickel Co	Basic. Peirce-Smith standard	2	2	10' 0"×25' 10'
Granby Cons. M. & S. Co.:	Basic. Power & Min-			,
Grand Forks	ing Mchy Co. acid shells	3	10	84"×126"
Anyox		9	9	10/ 0// × E/ 0//
B. C. Copper Co	type	3 2	3 5	12' 0"×5' 9" 84"×126"

Converting at the British Columbia Copper Co.'s Smeltery²

There are two hydraulic converter stands; seven 84×126 in. converter shells; a 40-ton NILES electric traveling crane; a 6-ft. Carlin silica mill, motor driven; a pneumatic tamping device; copper casting trucks, etc. A converter lining lasts two to three charges. The matte runs from 30 to 45 per cent.

The converter department produced per day about 30,000 lb. of blister copper, carrying about 7 oz. of gold and 30 of silver per ton. It required a crew of 21 men which, divided as follows into two 8-hour shifts, was able to handle all the matte produced:

Kind of labor	Day shift, 7 A.M. to 3 P.M.	Afternoon shift, 3 P.M. to 11 P.M.
Foremen	1	0
Converters	2	2
Crane	2	2
Laborers	3	1
Lining	5	$\bar{3}$
		_
Total	13	8

¹ From Peter's, "Modern Copper Smelting."

² Bull. 209, Canadian Dept. of Mines.
From a paper by F. K. Brunton, Trans. A. I. M. E., 1915.

Converter Blast.—According to STICHT, about 100,000 cu. ft. of air is required per long ton of copper produced from 50 per cent. matte and 165,000 cu. ft. of air for a long ton of copper from 40 per cent. matte. At one American works 183,000 cu. ft. of air is required per 2000 lb. of Cu produced.

Converter Costs.—As a rough basis for estimates on new work, \$4.50 per ton of matte could be taken as a minimum, and \$9.50 should be an outside figure for acid converting.

Basic should be a little cheaper.

Lining.—About 2 tons of copper will be produced per ton of

lining in the acid converter.

Gases.—The following analysis of gas passing through a converter flue is given by Dunn (Trans. A. I. M. E., 1913): SO_2 , 2.845 per cent.; SO_3 , 0.0515; CO_2 , 0.2084; H_2O , 1.061; As_2O_3 , 0.00073; O, 12.04; N, 83.64 per cent.

Sulphuric-Acid Manufacture

As the regions surrounding smelteries grow more densely populated, the difficulties caused by the discharge of sulphuric acid and sulphur dioxide into the atmosphere and the probability of being forced into sulphuric-acid manufacture increase. The contact-acid process does not seem successful for smelting plants, probably because of the arsenic in the fumes poisoning the catalyst. In the chamber process one has the ordinary chambers, the Meyer tangential system, the Falding high-chamber, and the still experimental lead spirals to choose from. The Falding system as adopted at the Tennessee Copper Co. was described by its inventor in the Eng. and Min. Journ. of Sept. 4, 1909, p. 443. In that article he makes the following comparison between the systems:

	Chamber space, cu. ft.	Ground area, sq. ft.	Weight of lining, tons
Old System	174,960	12,936	112
Old System Meyer tangential Falding	174,480 175,000	11,938 4,096	110 66.5

Acid manufacture at the Ducktown Sulphur, Copper & Iron Co.'s plant was described in the Journal of May 28, 1910, by W. H. FREELAND and C. W. RENWICK. That plant was designed for a capacity of 160 tons of 60° B. acid per day. Under normal conditions the gases delivered to the chambers analyze: SO₂, 3½ per cent.; CO₂, 3½ per cent.; and SO₃ trace. Temperature control of the gases is attained by small kite-shaped flues through varying lengths of which the gases can be run, until they are sufficiently cool. There are two Glover's towers, each 12 ft. square and 45 ft. high. Following these are four hard-lead fans (10 per cent. antimony) then two sets of eight chambers each. Each chamber is 96 ft. long, 22 ft. 8 in. wide and 30 ft. high. Special arrangements are said to be in-

troduced here to take care of the carbon dioxide in the gases.1 Six Gay-Lussac towers are used for recovery of the nitrous acid.

In a discussion of pyritic smelting and acid manufacture by Falding and Channing (Eng. and Min. Journ., Sept. 17, 1910) the necessity of a uniform composition of gas is insisted upon by these authors, and the general point made that an acid plant drawing its gases from several furnaces will more probably be successful than if it draws its gas from one.

The Anaconda Copper Co. in 1915 constructed a 100-ton acid plant, but this was as an adjunct to a leaching plant, and not to use blast-furnace gases. It was described by E. P. MATHEWSON in the Eng. and Min. Journ. of April 24, 1915.

Two 7-hearth Wedge roasters 22 ft. 6 in. inside shell diameter are used and the gases are led into a dust absorber 32 ft. in diameter by 44 ft. high over all. There are six niter pans. Gases from these mix with the sulphur gases in an octagonal Glover's tower 16 ft. across × 51 ft. high. There are 23 cooling chambers, 11 ft. diameter \times 36 ft. high and six $40 \times 96 \times 36$ ft. These are arranged five round, rectangular, three round, high. rectangular, three round, two rectangular, three round, rectangular, three round, rectangular, six rectangular. A hardlead fan, 8 ft. in diameter and 4-ft. face follows the first five round chambers.

There are 21 Gay-Lussac towers, circular in section, 7 ft. in diameter by 38 ft. high. They are constructed, except for the lead pans, of Duro-tile blocks laid in acid-proof cement with a packing of 72-hr. coke. The chamber space is 18 cu. ft. per pound of sulphur per day.

Miscellaneous Data for Lead Metallurgy²

ZINC	REQUIRED	FOR	DESILVERIZING	LEAD

Silver in lead, per cent.	Zinc required, per cent.	Silver in lead, per cent.	Zinc required, per cent.
0.025	1.25 (a)	0.3	2.00 (a)
0.05	1.33~(a)	0.38	1.84(b)
0.1	1.5 (a)	0.51	1.96(b)
0.15	1.66(a)	0.84	2.45(b)

¹ The matter of the ill effect of carbon dioxide in chamber work is by no means settled. Lunge says one Bohemian works with which he was acquainted made acid without trouble or special precautions from material

carrying 10 per cent. of bituminous matter.

In plants making sulphuric acid from pyrites, the inlet gases are considered to be best at 8.8 per cent. SO₂, 9.6 per cent. O₂; when burning brimstone, the gases should contain 10.65 per cent. SO₂, 10.35 per cent. O₂.

3 SCHNABEL'S "Handbook of Metallurgy." The Macmillan Co.

(a) According to ILLING. (b) According to JUNE.

NOTE.—At 350°C. lead dissolves 0.6 per cent. of Zn; at 650° it will dissolve 3.0 per cent. of Zn.

	Speiss, Leadville	Speiss, St. An- dreasberg	Matte, Pueblo	Matte, Pueblo	Raw matte, Clausthal	Roasted matte, Clausthal
Ag .	0.0085			•	0.0299	0.0327
Au	tr.	10.07		10.05	4 000	4 100
Cu Pb	0.3628	18.37	20.40	10.35	4.620	4.123
Mo	1.4935	66.84	8.50	12.45	10.665	10.492
Fe		0.22	41.20	42.50	53.112	52.411
Z n	tr.	0.04	1.50	3.10	2.110	2.459
Ni	0.0876	} 0.13			0.312	0.350
Co		J 0.13	,	•••••	0.312	0.500
S	5.1891		26.30	26.40		
	31.4725	tr.	tr.	0.12	26.877	0.613
$\mathbf{S}\mathbf{b}\dots$	tr.	3.60	tr.	0.05	0.267	0.128
SiO_2			0.20	0.30	0.510	1.486
CaO	1	10.60	0.16	$0.15 \\ 0.21$	0.383	0.336
Bi		tr.	0.10	0.21		• • • • • • •
Mn		VI.	1.40	3.30	0.385	0.317
O						22.966
SO ₃						4.225
	<u> </u>					

Effect of Steam on Molten Lead¹

If the temperature of the lead be below the melting point of zinc, steam will bring to the surface a zinc crust with some of the silver.

If the temperature of the lead be slightly above the melting point of zinc, the steam will cause a thorough mixing of the zinc and lead.

If the temperature be between a dark red and an incipient cherry red, the steam will cause a scum to rise, containing about 3 per cent. of zinc, which does not, however, take any silver away from the zinc.

If it be a clear cherry red, the zinc will decompose the steam; the zinc oxide, mixed with lead oxide, collects as a powder on the surface of the lead.

1 HOFMAN'S "Metallurgy of Lead."

Softening Lead¹

	Claus	thal	Laute	nthal	Freiberg		Denver	
	Before drossing	After dross- ing	Before drossing	After dross- ing	Before dross- ing	Liquated dross (5%)	Dross before liquat- ing	Dross after liquat- ing
Pb Cu Cd Bi Ag As Sb Sn Fe Zn Ni Co S O Slag,	98.92944 0.1862 Tr. 0.0048 0.1412 0.0064 0.7203 None 0.0064 0.0028 0.0023 0.00016 	0.1096 None 0.0050 0.1420 0.0053 0.7066 None 0.0042 0.0017 Tr.	Tr. 0.0082 0.1430 0.0074 0.5743 None 0.0089 0.0024 0.0068 0.00035	0.0907 None 0.0083 0.1440 0.0032 0.5554 None 0.0048 0.0015 0.0038	96.667 0.940 0.066 0.544 0.449 0.820 0.210 0.027 0.022 0.0055 0.200	None 0.17 2.32 0.98 0.04 0.43 0.07	53.0 18.2 2.0	50.0 26.8

PATTINSON'S PROCESS—CRYSTALLIZATION

(Ounces of Silver per Ton)

In the molten lead before crystallization	In the crystals	In the liquid lead
205.33	. 113.74-135.91	298.95
213.49	92.75 - 109.8	313.83
281.34	119.58 - 198.33	422.91
288.16	113.74 - 181.99	446.24
420.57	198.91 —	560.57
609.57	586.53 —	659.15
615.15	503.99 - 646.31	655.65

Results from experiment—not particularly concordant. "Berg- und Hutten-männische Zeitung," 1862, p. 251.

Zinc Table for a 30-ton Kettle²

FIRST ADDITION OF ZINC (TO REMOVE GOLD)

Up to 0.10 oz. gold per ton, 250 lb. zinc. From 0.10 to 0.30 oz. per ton, 300 lb. zinc. From 0.30 to 0.50 oz. per ton, 350 lb. zinc. From 0.50 to 0.70 oz. Au, 400 lb. zinc. From 0.70 to 0.90 Au, 450 lb. zinc, etc., etc.

<sup>HOFMAN, "Metallurgy of Lead."
By Eurich, taken from HOFMAN's "Metallurgy of Lead."</sup>

Second addi silver conte			tion to bring ents to 1 oz.		ition to bring nts to 0.1 oz.
Oz. Ag per ton	Lb. zinc	Oz. Ag per ton	Lb. zinc	Os. Ag per ton	Lb. sinc
40	15	<u>5</u>	225	0.2	60
50	50	7	265	0.3	75
60	100	10	320	0.4	90
.70	160	15	400	0.5	105
80	200	20	450	0.6	120
90	245	22	470	0.7	135
100	285	24	485	0.8	150
110	315	26	500	0.9	165
120	345	28	512	1.0	180
130	365	30	530	1.5	225
140	390	32	540	2.0	330
150	415	34	555	2.5	390
160	440	36	570	3.0	450
170	460	38	585	3.5	510
180	475	40	600	4.0	562
190	495	$ar{42}$	615	2.0	
200	515	46	630		<u> </u>
200	010	48	640	.	
		50	655		ilverising lead ened, for cop-
• • • • • • • •		52	670		removed com-
• • • • • • • •		54	680	pletely, arsen	ic to a trace,
• • • • • • • •	• • • • • •	5 6	695		not over 0.75
• • • • • • • •	· · · · ·	58	710		opper and tel- ine with sinc
• • • • • • • •	•••••		1 1		
• • • • • • • •	••••	60	734	does silver.	
• • • • • • •		62	747		

NEWTON'S experiments at Maurer (Bull. A. I. M. E., 1915, p. 474), conclusively showed that 535°C. is the best temperature at which to remove the zinc crusts. Carpenter and Whitley have shown that there is but one chemical compound formed between zinc and silver; this is Zn₃Ag₂, freezing at 665°C. It is soluble in lead at high temperatures.

Effect of Impurities on Refined Lead¹

Antimony and arsenic—render lead hard and less malleable. Said to render lead more easily attacked by hot sulphuric acid when antimony is over 0.2 per cent. This seems unreasonable. For corroding, lead may not have over 0.005 per cent. Sb. Tin, arsenic and antimony are oxidized in that order, and the products from softening lead may be separately worked up for these elements.

Bismuth—0.118 to 0.352 makes lead hard, somewhat crystalline and more fusible. Over 0.02 unfits lead for corroding.

Cadmium—tends to protect lead against sulphuric acid.

Iron.—Lead containing 0.07 per cent. Fe does not seem to lose in either softness or malleability. Corroding lead ought not to carry over 0.003 per cent. Fe.

Nickel and Cobalt.—These can readily be eliminated by slow

fusion.

Tin—makes lead light gray, hard and increases fusibility. Is readily removed by heating in air.

Zinc.—Corroding lead ought not to carry over 0.003 per cent.

Zn.

Typical Lead Smelting Furnaces

•	Dimensions at tuyères, inches	i Kirbet.	_	Capacity per 24 hr.	Remarks
U. S. Smelting Co., Midvale ¹ Tintic Sm. Co., Tintic, Utah ¹ A. S. & R. Co., Pueblo, Colo. ¹ . A. S. & R. Co., Denver, Colo. ¹ . A. S. & R. Co., Murray, Utah ¹ Port Pirie, Australia ¹ , ³ A. S. & R. Co., Perth Amboy, N. J. ¹ . Laurium, Greece ¹ Herculaneum, Mo. ² Peñoles, Mapimi., Mex. ² . A. S. & R. Co., Perth Amboy,	48×160 48×148 42×144 48×164 62×212 44×128 48×160	32-34 34 32 34 30 35 35-40	20 21 16		Mech. feed Coke, 12% Mech. feed Coke, 12% Coke, 14% Coke, 14%
N. J. ² . A. S.&R. Co., Monterey, Mex. ² A S.&R. Co., Chihuahua, Mex. ²					

¹ Hofman, "Metallurgy of Lead."

¹ From Gowland's "Metallurgy of the Non-ferrous Metals," p. 155.

² Private notes. * It would appear that the Port Pirie furnace is the largest operating.

ZINC SMELTING1

Effect of Impurities in Smelting:

Alumina—may be objectionable, as zinc spinel may be formed.

Arsenic and Antimony.—These are partly reduced and volatilized, and appear in traces in the spelter.

Cadmium.—Cadmium is more easily reducible and more volatile than zinc, and collects in the first dust and metal, which can then be used as a source of this metal.

Calcium.—Lime alone is beneficial, as it tends to decompose zinc sulphide. See Silica, above.

Fluorspar.—This is an undesirable constituent because it forms fusible slags which attack the retorts.

Gold and Silver.—These remain chiefly with the retort residues and can be recovered from them by resmelting.

Iron and Manganese—should not be present as sulphide, as it corrodes the retort. Also forms fusible slags with silica, which corrode the retort. Ten per cent. Mn + Fe represents about the upper limit of safety.

Lead.—The chief objection to lead is that its compounds are reduced and some lead distils over with the zinc.

Magnesia—acts much like lime, but magnesian slags are less fusible than calcareous.

Silica—is inert alone, of no particular consequence when lime is present, but is harmful if both lime and iron are constituents of the charge since ferrous-lime silicates are extremely fusible.

Sulphur—decreases the yield of zinc, since the sulphide is not decomposed by carbon. Ferrous sulphide corrodes the retort.

In general, either highly acid or highly basic charges must be used, there must be a little space above the charge, and the

charge should not be too finely pulverized.

The formation of zinc spinel occurs to a larger extent in hand-made than in machine-made retorts; it is diminished greatly by addition of coke to the mass used for making the retorts. During smelting the slag takes up considerable quantities of silica and alumina from the retorts, and a viscous layer, intermediate in composition between the slag and the retort, is formed, which tends to prevent rapid destruction of the latter. It is only at the higher temperatures prevailing toward the end of the distillation that there is any pronounced destructive action of the slag on the retorts. The absorption of zinc oxide by the clay used for making the retorts, and its fixation as aluminate, increases with the pressure, temperature, and time.²

¹ W. R. INGALLS, "Metallurgy of Zinc and Cadmium." ² Metall. und Erz., 1914, pp. 333, 337, 412, 553.

Miscellaneous Data for Zinc Smelting Blue Powder Production (Zinc Smelting)

Blue powder	I	11	III	IV	v	VI
Zn. Pb. Fe. Cd. As, Sb. C. Insol. Zinc ore: Zn. Pb. Fe. Cd. S. As. Sb. CaO. MgO. SiO ₂ .	(a)90.11 0.82 0.10 0.005 Nil } 3.33 47.00 3.80 10.34 0.005 1.08 Tr. Tr. 4.00 0.60 10.00 A	(b)94.04 2.50 0.30 1.30 	(a) 91.50 0.50 0.18 0.50 0.16 ? 	1.50 2.50 50.00 5.50 8.50 ?	(d) 88.80 1.90 1.32 1.80 Tr. 4.10 Tr. 48.50 6.50 8.30 0.18 2.50 0.02 0.04 6.00 13.80 I	1.98 0.79 0.52 Tr. 3.11 Tr. 44.50 9.30 12.50 0.25 3.40 0.02 0.03 4.50

⁽a) A small portion in the form of ZnO. (b) Metallic zinc, 88.74 per cent.; ZnO, 6.60 per cent. (c) Metallic zinc, 85.34 per cent.; ZnO, 12.66 per cent. (d) Metallic zinc, 79.16 per cent.; ZnO, 11.26 per cent. (e) Metallic zinc, 85.24 per cent.; ZnO, 7.54 per cent.

W. R. Ingalls, "Metallurgy of Zinc and Cadmium."

Residues produced	I	II ·	III	IV	v	VI
Zn. Pb. Fe. Ag. Cu. Cd. As. Sb. S. CaO. MgO. SiO ₂ . C. Al ₂ O ₃ .	4.00 5.00 16.55 0.016 0.05 Nil Nil Nil 2.50 0.45	2.50 8.50 14.50 ? ? ? ? 4.00 2.50 1.50	3-7 1.26 ? ? ? ? ?	4.00 10.00 ? 0.01 ? 8.00 ? {17.50 ?	3.40 8.10 ? 0.05 ? ? 2.10 ?	4.20 9.50 ? 0.085 ? ? 3.50 ?

On attempting a jigging of the above, these products were obtained:

ROASTING LOSSES

Tests on the roasting losses on zinc ores are given by Ingalls¹ as follows:

	Sample					
•	I per cent.	II per cent.	III per cent.	IV per cent.	V per cent.	
Zinc	31.00	41.80	43.93	47.50	42.60	
Sulphur	22.26	27.40	24.95	33.26	29.07	
Lead	7.50	4.00	7.35	2.15	8.75	
Iron		3.00	5.20	13.60	7.50	
Lime	1.60	1.40	0.10		0.12	
Magnesia	0.65	0.80	0.15	1.20	1.10	
Baryta		10.55				
Quartz	2.75	10.20	15.46	1.14	10.00	
Total	94.21	99.15	97.14	98.81	99.14	
Loss per cent. Zn		10.05	11.25	12.70	12.00	
per cènt. Ag	11.77	10.68	12.15	11.22	12.00	

For complete desulphurization a temperature of 900°C. (orange color) should be obtained.

GASES FROM ZINC RETORTS (LETMATHE)1

	Befo	re		Durin	ng distille	tion	
	distilling begins		1	2	3	4	5
CO ₂ CO CH ₄ H	15.8 38.8 4.1 41.7	52 17 70	0.48 not det. not det. 5.32 not det.	1.06 92.16 1.83 1.01	97.12 not	not det. det.	0.82 98.04 · 0.72 tr.
		Co	MPOSITION	of Zin	c Fum	E ²	····
ZnZnO ZnO CdO Pb SO ₃ Mn ₃ O ₄ Fe ₂ O ₃ Insol			88.20 1.46 4.00 4.12 0.05 1.50	0	.23		74)1
			99.33	98	.03	100.1	14

¹ SCHNABEL, "Handbook of Metallurgy," Vol. II, p. 108. The Macmillan Co² Ibid., p. 176. As can be seen, this is a most variable product.

¹ INGALLS, "Metallurgy of Zinc."

Zinc Distillation Temperatures

According to INGALLS

In the retort: beginning, 781; end, 1188.

In the furnace: 1067; end, 1309.

Interior of furnace near middle wall where the gas is introduced, about 1315°C.

CAPACITY AND WEIGHT OF CYLINDRICAL RETORTS1

- ,,	7 in.	diam. insi	de	8 in. diam. inside			
Length outside, in.	Outside vol., cu. in.	Inside vol., cu. in.	Wt. lb. (a)	Outside vol., cu. in.	Inside vol., cu. in.	Wt. lb. (a)	
. 46	2926	1693	86.3	3613	2212	98.1	
47	2990	1732	88.0	3691	2262	100.0	
48	3054	1770	89.9	3770	2312	102.1	
49	3117	1809	91.6	3848	2362	104.0	
50	3181	1847	93.4	3927	2413	106.0	
51	3244	1886	95.1	4006	2463	108.0	
52	3308	1924	96.9	4084	2513	110.0	
53	3372	1963	98.6	4163	2564	112.0	
54 -	3435	2001	100.4	4241	2614	113.9	
55	3499	2040	102.1	4320	2664	115.9	
56	3563	2078	104.0	4398	· 2714	117.9	
57	3626	2117	105.6	4477	2764	119.9	
5 8	3690	2155	107.5	4555	2813	121.9	

DIMENSIONS OF ZINC RETORTS USED IN THE UNITED STATES¹

Place	Cross section	Length, in.	Diameter, in.
Carondolet Collinsville Friedensville Lasalle Jersey City Jersey City Peru Pulaski Pittsburgh So. Bethlehem	Circular Circular Circular Circular Elliptical Elliptical Elliptical Circular	48 46 54 54 54 54 51	8 8 8 8 7 7×9 7½×11 8×10 8 6¾×12½

W. R. Ingalls, "Metallurgy of Zinc and Cadmium."

¹ W. R. Ingalls, "Metallurgy of Zinc and Cadmium."
(a) After burning. An old retort will carry 12-18 per cent. of its weight in sinc.

Retort Duty.—According to INGALLS, a production of about

4½ tons of spelter per retort per year is a safe estimate.

Glazing.—Sometimes the retorts are glazed when dry in order to make them impervious to the passage of gas. Lead glazes may not be used; more often porcelain and salt glazes are used. The porcelain glaze consists of 84 parts ground feld-spar, 35 parts calcium carbonate, 26 to 91 parts china clay and 54 to 204 parts quartz sand. It is not necessary that the glaze be quite white. The glaze is made into a mixture with gum arabic, dextrine or some other paste and painted on the inside of the retort to a thickness of about 1/6 in.

CADMIUM-BEARING	FLUE	Dusts ¹
-----------------	------	--------------------

	Si	lesia works		Go		
·	8olu- ble	Insoluble	Total	Solu- ble	Insoluble	Total
ZnO PbO CdO TlO FeO MnO Fe2Os Al2Os CaO MgO As2Os P2Os SOs H2O Residue	0.874 0.006 1.896 1.332 2.900 0.714 0:168 20.430 11.400	6.285 1.147 	6.285 2.021 0.006 1.896 1.376 15.058 1.192 0.608 0.401 0.263	1.120 0.006 1.676 0.481 2.940 1.191 0.464 1.337 13.320 4.850	1.591 (Mn ₂ O ₄) 15.928 4.601 1.071 0.858 1.280 0.394 9.061	20.523 8.980 2.638 0.006 1.676 2.072 18.868 5.792 1.535 2.195 1.280 0.394 22.381 4.850 6.804

Smelting Zinc Ores by Electricity

The following estimate of electric zinc smelting is given by Dorsey A. Lyon and Robert M. Keeney, in a paper before the San Francisco meeting of the A. I. M. E., September, 1915:

Although more progress has been made hitherto in the electric smelting of zinc ores than in that of any of the non-ferrous metals except aluminum, and metals forming ferro-alloys, such as silicon, chromium and tungsten, the process is nevertheless still largely in the experimental stage. There is no plant operating on a commercial scale except the Trollhättan works, taking from 10,000 to 13,000 hp. There are about twenty-four furnaces installed at this plant, each requiring from 400 to 1200 hp. The same company, the Norse Power & Smelting Syndicate, also has a smaller plant near Trolhättan at Sarpsberg, where there are seven small furnaces. One other small commercial plant is in course of erection at Keokuk, Iowa, by the Johnson Electric Smelting Co. It appears that the experiments conducted at Hartford, Conn., for several years have

¹ SCHNABEL's "Handbook of Metallurgy." The Macmillan Co.

proved successful enough to warrant the installation of a small commercial unit to test the process further. The Johnson process and the Trollhättan process are essentially the same. Johnson claims to have overcome the problem of condensation

of zinc vapor into zinc instead of blue powder.

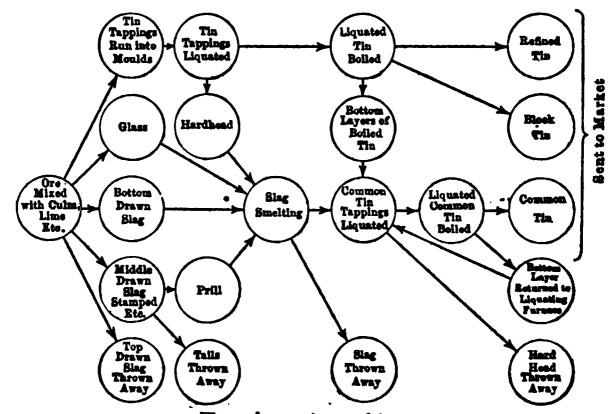
From the work at Trollhättan and the results of others, it is evident that the difficulty in electric smelting of zinc ores lies almost entirely in the condensation of zinc vapor to a metal, rather than blue powder, under the peculiar conditions of the electric furnace. The electric furnace presents no great difficulties, mechanically or electrically, because all the troubles formerly experienced have been solved in the construction of large pig-iron, steel, carbide and ferro-alloy furnaces. The problem, then, is one of a metallurgical nature, and is caused by the different conditions and greater speed of smelting in the electric furnace, as compared with the combustion retort.

While this problem is difficult, there is no reason why it should not be worked out in time. When it has thus been rendered unnecessary to resmelt a large proportion of blue powder (as at Trollhättan, where 2 tons of blue powder are smelted for each ton of ore treated), it is probable that electric zinc smelting will proceed rapidly in favorable localities. The use of iron as a desulphurizing agent does not seem to have advanced as far as the reduction of oxide with carbon, and it is probable that the

latter will keep its present supremacy.

TIN SMELTING

In British practice with ore assaying 65 to 71 per cent., the charges are: Ore, 80 cwt.; culm, 10.4 cwt.; refinery dross, 2.4 cwt. For ore above 71 per cent. increase the culm. This



Flow sheet, tin smelting.1

¹ From Louis, "Metallurgy of Tin," p. 96.

will give from 4500 to 4800 of tin assaying about 99.5 per cent. of tin, and 2200 to 2500 lb. of rich slag, carrying 35 per cent. of tin. This slag is then smelted as follows: Rich slag, 30 cwt.; rough-metal dross, 12 cwt.; scrap iron, 2.75 cwt.; anthracite, 6 cwt.; coral, 2.4 cwt. It may be noted in operations where tin is on the furnace charge, that it will be carried into either too silicious or too basic a slag, as it forms silicates and stannates and stannites.

Tin Smelting by Electricity

The electric furnace should be appropriate for the smelting of tin ores, since the reduction of tin oxide by carbon requires a very high temperature especially if impurities are to be eliminated. The reduction by carbon produces partly carbon dioxide and partly carbon monoxide, and theoretically would require 665 kw.-hr. per ton of ore. The theoretical amount of energy per ton of ore smelted may be estimated as follows:

Reduction	665 kwhr.
Slag	130
Heating tin	65
Heating tin	130
Gases	150
· Total	1140 kwhr.

Experiments on tin smelting, conducted by H. HARDEN in Cornwall, were described in the *Mining Journal* of London, in The current was a three-phase, alternating, of 50 cycles, 650 to 675 volts. A shaft furnace was used containing 3 electrodes and the formation of a direct arc was avoided. charge formed a cone around the reaction zone, in which the electrodes burned freely, surrounded by incandescent gases which served as resistance. The three factors, yield of tin, consumption of energy, and losses in slag, are closely interrelated. It is easy to obtain a slag containing only 0.25 per cent. of tin, but the process is not economical, as the consumption is 3000 kw.-hr. per ton of metal. When the slag contains 17 to 19 per cent. of tin the consumption of energy is reduced to 1300 kw.-hr. per ton of metal, but this is not economical. On a recovery of about 96.75 per cent. of the tin in the ores, the consumption was 2200 kw.-hr. per ton of metal. The consumption of electrodes was 12.7 kw. per ton of metal. Arsenides and sulphides of iron were introduced at regular intervals to avoid the formation of hard slag, obtaining a metal containing 98 per cent. of tin from This metal was afterward refined in shaft very impure ores. furnaces containing iron tubes for the injection of air. HARDEN'S conclusions are that the electric process can be advantageously employed in places where the ores are good but not very rich, and where waterfalls can be utilized for supplying the power needed.

NICKEL-COBALT-COPPER SMELTING

In smelting nickel, copper and cobalt together under such conditions as to form a matte and a speiss, it is the general tendency of the copper to enter the matte in preference to the nickel, and for the nickel to enter it in preference to the cobalt. Some subjoined analyses from Schnabel illustrate this very well. The furnace charge (at Altenau) was a leady copper slag, smelted with iron and arsenical pyrites.

	Ni,CO	Cu ,	Fe	Pb	As	Sb	8
Speiss	26.77	19.85	15.82	12.14	12.15	10.01	4.57
Matte	6.10	37.24	20.84	16.10		0.47	19.25

The speiss was roasted, then resmelted with heavy spar, arsenical pyrites, copper-refinery slags, and slag from lead-matting giving:

	Ni	Co	Cu	Fe	Pb	·As	Sb	8
Speiss	35.13	10.70	17.18	8.41	6.59	18.65	10.82	2.16
Matte	4.37		37.45	12.68	22.81	tr.	tr.	24.48

Smalt is a highly siliceous potash glass colored blue with cobalt monoxide (from 1.95 to 18 per cent.). In the commercial manufacture cobalt ore is usually partially roasted, leaving enough arsenic to form speiss with the iron, nickel, copper and part of the cobalt and melted with washed pulverized silica and potash. Allowing a small quantity of cobalt to enter the speiss insures the absence of nickel from the smalt. The glass after prolonged fusion and stirring is finally poured into water, stamped, jigged to free it from entrained speiss and sieved.

Typical analyses according to Schnabel are:

	Coarse color	Second grade pigment	Coarse pale colo	
SiO ₂	70.86	66.20	72.12	
Al_2O_3	0.43	0.64	1.80	
FeO	0.24	1.36	1.40	
CaO			1.92	
CoO	6.49	6.75	1.95	
K₂O	21.41	16.31	20.04	
Ni			tr	
As ₂ O ₃	tr		0.078	
CO_2		0.25	0.46	
H ₂ O	0.57	0.67	tr	
·	100.00	92.18	99.768	
	100.00	<i>52.</i> 10	00.	

MERCURY SMELTING

The treatment of quicksilver ores as practised at the Oceanic Mine, Cambria, Calif., probably represents the best practice in the United States. This was described by C. A. Heberlein (February meeting, 1915, A. I. M. E.), the following being an abstract of his paper. Wet ores are first concentrated and then treated in the Scott furnace, but the dry ores are charged direct. The ore is crushed at the mine to about 1½ in. diameter and brought to the plant by bucket tramway. The wet ore goes to a 3½ ft. Huntington mill provided with a 16-mesh screen. The undersize goes direct to a Deister table.

The gangue is more friable than the mineral and little sliming takes place. The feed contains about 0.3 per cent. Hg, and the concentrates about 5 per cent. Hg. The extraction is about 80 per cent. and concentration about 20:1. Costs are about 50 cts. per ton. Flotation has been tried on quicksilver ores but the process does not appear to be a commercial one as fine grinding costs about as much as the ordinary furnace process; and the oil sticking to the concentrates would distil over with the mercury, making the "soot" more difficult to

treat.

The furnace is a 50-ton Scott furnace. The sealing apparatus is said to be highly effective. (A cut of this is given in the *Transactions* of the A. I. M. E., to which reference is made.) Fuel consumption is said to be 15 cords of wood per month, treating 750 tons of ore and producing about 100 flasks of

quicksilver.

At the plant the condensers after the first one are no longer built of brick, but of redwood, connected by a cast-iron downtake with the furnace. The gases entering the condenser are hardly over 250°C. and as drawn off from it are about 170°C. These wooden condensers are square wooden boxes of tongue and groove construction. The gases are admitted at the top and drawn off at the bottom. All baffling, etc., is unnecessary. The tops of the wooden condensers are water cooled. About 1000 gal. of water run out daily from the second (first red-wood) condenser, representing the condensed moisture from the ore. This is highly acid and carries quicksilver in solution.

A 50-ton Scorr furnace with all accessories cost about \$25,000 on a pre-war price basis. Direct smelting costs about 47 cts. per

ton.

No analyses of soot is given, but some taken from European practice are appended.

578 METALLURGISTS AND CHEMISTS' HANDB O

MERCURY SMELTING

Analyses of Mercury Soot from Distillation Furances¹

Mercury	56.30	6.42	3.12
Mercuric sulphide	0.70	2.20	31.10
Mercuric sulphate	18.99	13.07	10.80
Mercurous chloride	2.20	1.80	1
Sulphuric acid	1.10	4.80	1
Magnesia		1.10	
Lime	0.76	1.20	
Ferric oxide and alumina	tr.	0.80	1
Calcium sulphate	1.04	6.30	
Basic ferric sulphate	3.24	0.40	
Soot and tar	33.9	29.40	24.80
Water	4.60	26.50	10.30
Ore residues	11.41	3.80	2.20
Magnesium sulphate			7.50
Sodium sulphate			1.24
Ammonium sulphate			0.54
Ferrous sulphate			

The mercury is extracted from these residues by pressing, followed by retorting.

¹ SCHNABEL, "Handbook of Metallurgy," Vol. II. The Macmillan Co.

COPPER REFINING

Elimination of Impurities in Reverberatory Refining of Copper¹

	Cu	Fe	s	Pb	Bi	Sb
Before After	98.283	0.062	0.2576	0.5382 0.1100	0.0045 0.0101	0.1853 0.1527
Before After	99.399	0.036 0.004	0.086 0.0009	0.029 0.006	0.017 0.007	0.032 0.007
Before After	99.475	0.013 0.004	0.088 0.006	0.007 0.004	0.001 0.003	0.129 0.017
	As	Те	Se	Ni	Ag ounces	Au ounces
Before After	0.1709 0.1502	0.0054 0.0195	Trace Trace	0.0473 0.0539	59.91 61.7	0.276 0.27
Before After	0.054 0.010	0.014 0.003	0.010 0.009	0.008 0.009	68.17	0.204
After After	0.067 0.045	0.006 0.003	0.005 0.007	0.009 0.013	39.893	0.251
	_ 			<u> </u>	.L	<u> </u>

ELIMINATION OF IMPURITIES IN CUPOLA (BLACK COPPER SMELTING)

	Cu	Pb	Bi	Sb	As	Te & Se
Refining furnace slag Cupola slag Black copper Per cent. elimination	97.7	0.78	0.002 0.0 0.035 0.0	0.0317	0.0033	0.0026 0.0 0.0095 0.0

In refining blister copper to anodes Keller gives the following table of relative slaggability of the various metals:

 Cu
 Pb
 Bi
 Sb
 As
 Te, Se

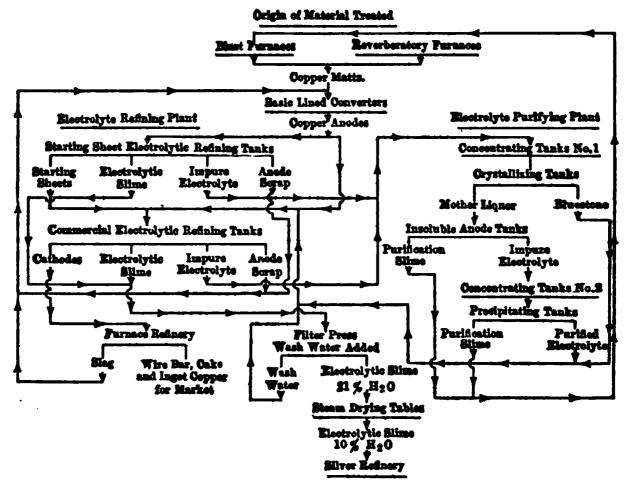
 1
 52.1
 1.07
 5.90
 5.07
 0.84

This omits volatilization losses, which would be higher for the last four elements than for the first two ("Mineral Industry," 1901, p. 248).

¹ Private notes.

In the converter, Keller figures that the percentage eliminations of impurities are as follows:

Fe $\mathbf{Z}\mathbf{n}$ Sb Co Bi Te Se 99 99 99 99 37 96 97 71 81 **40** These may serve as the slaggability ratios in the old acid-lined converters.



Flow sheet of Great Falls Electrolytic Plant¹

Electrolytic Refining Current Losses²

320 tanks—22 anodes, 22 cathodes per tank—90 per cent. amp. eff.—2-day cathodes.

	Volts per tank	Volts per 320 tanks	Percentage distribu- tion
Voltage drop—bus bar to anode.		14.08	7.40
Voltage drop through electrolyte		158.72	83.36
Voltage drop—cathode to bus bar		17.60	9.24

¹ W. T. BURNS, Trans. A. I. M. E., August, 1913. ² R. S. McCaffery, in the "Wisconsin Engineer."

Converter and Furnace-refined Copper Anodes¹
Comparison of Converter and Refined Anodes Cast in the Same Moulds

	Converter anodes	Refined anodes
Number of days covered by test	50.0	50.0
Number of refining tanks employed	48.0	48.0
Average analyses of anodes:		
Per cent. Cu	98.91	99.27
Per cent. As + Sb	0.072	0.071
Ounces Ag per ton	59.09	61.14
Ounces Au per ton	0.200	0.219
Average analyses of electrolyte:	•	
Specific gravity	1.20	1.20
Grams per liter Cu	43.5	43.5
Grams per liter free acid	160.0	160.0
Grams per liter As	11.97	11.97
Grams per liter Sb	0.49	0.49
Grams per liter Fe	10.09	10.09
Grams per liter Cl	0.045	0.045
Average temperature of electrolyte:		
Inlet of 8-tank cascade, C.	58.0	58.0
Outlet of 8-tank cascade, C.°	54.0	54.0
Rate of circulation of electrolyte, gal. per min	6.0	6.0
Number of anodes per tank	20.0	20.0
Number of cathodes per tank	20.0	20.0
Average weight per new anode, lb	525.0	632.0
Average thickness per new anode, in	3.0	3.0
Distance, center of anode to center of cathode, in.	2.87	2.87
Active cathode surface per tank, sq. ft	$25\overline{2.0}$	252.0
Average amperes per tank	8,387.0	8,387.0
Average volts for 48 tanks	27.21	28.53
Average volts per tank	0.567	0.594
Average kilowatts for 48 tanks	228.2	239.3
Total copper deposited, lb	1,103,749	1,148,749
Average age of cathodes drawn	234	21/2
Average ampere efficiency of deposit, per cent	88.3	91.9
Average amperes per sq. ft. cathode surface	33.3	33.3
Average lb. copper deposited per kilowatt-hour.	4.03	4.00
Average os. per ton silver in cathodes	1.25	0.95
Average per cent. As + Sb in cathodes	0.0043	0.0043
Average per cent. anode scrap.	8.00	5.30
Analyses of silver slime:	0.00	0.00
Per cent. Cu	40.3	18.80
Ounces Ag per ton	6.755.00	14,079.0
Ounces Au per ton.	18.34	38.45
Outros Au Per von	10.07	00.70

The chief disadvantages of converter anodes are: lower grade slimes; higher losses of silver in the cathodes; and higher percentage of anode scrap. However, Mr. W. T. Burns states that the losses due to these factors are not equal to half the cost of reverberatory refining.

Starting-sheet Tank Electrolyte

Specific gravity	1.175
Free H ₂ SO ₄ , grams per liter	120.0
Cu, grams per liter	4 0. 0
As, grams per liter	5.0
Sb, grams per liter	0.4
Fe. grams per liter	4.5
Cl, grams per liter	0.04

¹ Trans. A. I. M. E., August, 1913.

Elimination of Impurities in Electrolytic Refining

According to Keller's figures about 99.92 per cent. of the copper in the anode goes into solution, the remainder to the slime; from 61 to 78 per cent. of the bismuth goes into the slimes, 30 to 60 per cent. of the antimony (according to conditions worked under), 23 to 38 per cent. of the arsenic; while the silver, gold, selenium, tellurium and lead are quantitatively slimed ("Mineral Industry," 1898, Vol. VII, p. 239). Nickel is slimed if it is present as oxide in the anode copper; dissolved if present as metal. Cobalt, zinc, manganese and iron go into solution.

Work in Insoluble-anode Tanks1

REMOVAL OF COPPER, ARSENIC AND ANTIMONY FROM ELEC-TROLYTE IN INSOLUBLE-ANODE TANKS

(Circulation, 4 liters per minute. Lead anodes, copper cathodes, 9000 amp., 31.8 amp. per square foot)

	Grams per liter					Volts	Tem-
	Acid	Cu	Fe	As	Sb	per tank	pera- ture, C.º
Inlet tank No. 1 Outlet tank No. 1 Outlet tank No. 2 Outlet tank No. 3 Outlet tank No. 4	144 184 194 208 216	37.060 7.376 0.504 0.088 0.048	7.364 7.701	3.200 2.240 0.400 0.056 0.028	0.463 0.260 0.061 0.038 0.028		17 42 57 64 65

CORRECTED ANALYSES²

-	Grams per liter				eli: of	rcent minat origi moun	Ampere effi- ciency,		
	Acid	Cu	Fe	As	Sb	Cu	As	Sb	per cent.
Inlet tank No. 1. Outlet tank No. 1 Outlet tank No. 2 Outlet tank No. 3 Outlet tank No. 4		6.760 0.427 0.071	6.242 6.242 6.242	2.050 0.339 0.045	0.4630 0.2380 0.0517 0.0308 0.0220	81.8 17.1 0.9	53.5 9.2	40.2 4.7	19.50
Total and average	• • • •					99.9	99.3	95.3	23.26

See p. 584 for some notes on lead, duriron and tantiron as insoluble anodes.

¹ W. T. Burns, Trans. A. I. M. E., August, 1915. ² Calculated to the same value for iron, which is not affected in the insolubleanode tanks.

COPPER REFINING-ANALYSES OF TYPICAL PRODUCTS

Orude tas lexing	None 0.0023 0.0048 19.27	0.0140	0.0574	
rad siiW taub suft	31.49	2.80 0.01 Trace	4.19	32.61
-tui əbonA əufi əsan taub	11.10	3.20 0.20 0.01	7.39	29.48
euft semil8 •taub	1.70 5.51 17.04	3.20 0.015 19.52	1.38	
Blue stone	25.07 	0.170		
Blue stone	24.89	0.245		
Casting Teques	99.34 0.4237 0.1092 0.0795	0.0136 0.0026 Trace		
Slimes flue taub	2.10 4.85 15.36	2.460 0.003 7.84		
Refining- furnace anodes	98.21 0.1492 0.1716 0.1050	0.0208 0.0177 0.6050 0.0270 0.0544	0.0720 0.0350 0.0250 Trace	
Elec- trolytes	2.51 0.5523 0.0451 1.23	0.0033 0.1456 None None None	None 0.0226	0.0048
Elec- trolytic ¹ elime per cent.	43.3400 3.0300 3.4600 0.0800	0.1100 0.3640 17.1870 0.1200 1.2000	2.1000 0.7600 0.0900 13.2100	0.1770 0.0260 0.5900 0.000166
Wire bar, 1 per cent.	99.9500 0.0016 0.0015 0.0006 Trace	0.0004 0.0006 0.0030 Trace	Trace 0.0001 0.0025 0.0350	
Elec- trolyte, ¹ per cent.	3.280 0.500 0.941 0.377 0.016	0.021 0.600 None None	None Trace 0.418	0.0040 13.0300 1.220
Converter anodes, 1 per cent.	99.1300 0.1183 0.0534 0.0420 0.0018	0.0038 0.0110 0.1371 0.0008 0.0090	0.0170 0.0065 0.0035 0.2610	
	Copper Arsenic Antimony Niokel Cobalt	Bismuth	Tellurium Lead. Zinc. Sulphur Oxygen.	Silica. Chlorine. Carbon. Platinum. Free sulphuric acid

¹ First four columns from Willis T. Burns' "The Great Falls Electrolytic Refinery," *Trans. A. I. M. E.*, Aug., 1913.
² Eastern practice.
³ Near slimes furnace.

Slime from Insoluble-anode Tanks

(Treating electrolyte direct from tank room)

Moisture, per cent.	10.0	As, per cent	10.3
Cu, per cent		Sb, per cent	2.5
SiO ₂ , per cent		Ni, per cent	0.35
FeO, per cent		Zn, per cent	0.32
Al ₂ O ₃ , per cent		Ag, oz. per ton	3.4
CaO, per cent	0.3	Au, oz. per ton	0.02
S. per cent	. .	•	

Better results are secured from the insoluble-anode tanks at Great Falls when the electrolyte from the tank room is boiled until it reaches a specific gravity of 48°Be. It is then crystallized for 4 days, when the mother liquor then analyzes: acid, 475; Cu, 17.4; As, 20.2; Sb, 1.1; and Fe, 15.2 grams per liter. This is then electrolyzed to remove Cu, As and Sb.

Analysis of Insoluble-anode Tank Slime

(Treating mother liquor from crystallizing tanks)

Moisture, per cent	9.66	As, per cent	21.48
Cu, per cent		Sb, per cent	2.28
SiO ₂ , per cent		Ni, per cent	0.35
FeO, per cent		Zn, per cent	0.32
Al ₂ O ₃ , per cent		Ag, oz. per ton	3.61
CaO, per cent	1.08	Au, oz. per ton	0.03
S, per cent	5.02	•	

Materials for Insoluble Anodes

The usual materials for insoluble anodes are platinum, carbon, iron and hard lead, according to the nature of the electrolyte. Fused magnetite anodes are also being used, notably at Chuquicamata, Chile, but they are extremely expensive and very brittle. However, when the anodes do not have to be handled often, i.e., are not subject to chance of breakage by carelessness, and can be guarded from sudden large changes of temperature, they are unquestionably the finest anodes obtain-In ordinary copper tank-room practice hard-lead anodes are usually used in the insoluble-anode tanks. Herewith follow some notes, not hitherto published, furnished by F. R. PYNE, assistant superintendent of the United States Metals Refining Co.'s copper refinery, giving parallel tests on hard lead, duriron, and tantiron electrodes, using them as anodes in various electrolytes. The current density was about 20 amp. per square foot. In a 12 per cent. sulphuric-acid solution the tantiron lost 0.94 per cent. in 24 hours, the duriron lost 7.30 per cent. in 42 hours and the hard lead, 0.69 per cent. in 30 hours. In regular tank-house electrolyte of approximately 3 per cent. copper, 10 per cent. sulphuric acid, the tantiron lost 1.88 per cent. in 48 hours, the duriron 10 per cent. in 60 hours, the hard lead, 0.44 per cent. in 36 hours, and on another test in the same solution the hard lead showed a loss of 1.71 per cent.

in 48 hours. Tests made by the New England Manufacturing Co. in nitric acid electrolyte were as follows: The current used was 3 amp. per sq. in., 18 sq. in. of tantiron in 1.39 sp. gr. nitric acid lost 0.480 grams in 5 hours; 3 sq. in. of duriron lost 0.0036 grams in 6 hours in nitric acid of the same strength. Duriron anodes have also been used in the Chuquicamata electrolytic plant of the Chile Exploration Co. Regarding this, Mr. C. A. Rose says in the Engineering and Mining Journal of Feb. 19, 1916: "While this material is not entirely unacted upon when used as an anode in copper-sulphate solution, from 15 to 20 times its weight of copper can be deposited before it is entirely corroded away. Duriron anodes have an advantage over magnetite in their mechanical strength, but they have a much higher over-voltage, which is a decided disadvantage. About 15 per cent. more electrical energy is required with duriron than with magnetite anodes for the deposition of the same quantity of copper."

As against a deposit of 8 to 8.5 lb. of copper per kilowatt-hour using the multiple process and 10.5 to 11.5 per kilowatt-hour when using the series process, ordinarily only about 1 lb. per kilowatt-hour is obtained with insoluble anodes. However, by using ferrous sulphate as a depolarizer at the anode, a certain amount of aluminum sulphate as a substitute for a diaphragm,

Comparison of Series and Multiple Refining

	Multiple	Cast-series
Ampere efficiency	90.0	68.0
Volts per tank	0.3	18.0
Anodes per tank	28.0	120.0
Cathodes per tank	29.0	120.0
Amp. per square foot	18.0	16.0
Daily deposit per tank	204.0	2040.0
Lb. Cu per kilowatt-hour	- 7.79	11.79

RESISTANCE OF ELECTROLYTES, COPPER REFINING1

Strength	Cui	SO₄	Fel	SO ₄	H ₂ f	804
solution.	Ohms per	Ohms per cu. in.	Ohms per	Ohms per cu. in.	Ohms per	Ohms per cu. in.
2.5 5.0 7.5 10.0 15.0 17.5 20.0	92 53 31 24 22	37 21 12 10 9	65 34	26 14	4.8 2.5 1.8	1.9 1.0 0.7
25.0 30.0			25	io	1.4 1.37	0.56 0.55

¹ J. W. RICHARDS, "Metallurgical Calculations."

and reducing the ferric sulphate formed in the depolarizing, by means of sulphur dioxide, Addicks claims to have obtained as high as 2.25 lb. per kilowatt-hour. He also claims that when suitably depolarized, carbon anodes will stand up in a sulphate electrolyte. ("Electrolysis of Copper Sulphate Liquors, using Carbon Anodes," joint meeting A. I. M. E. and A. E. S., San Francisco, Calif., Sept. 17, 1915.)

Electrolytic Lead Refining.—In a refinery operating under commercial conditions the ampere efficiency in lead deposition was 88.5 per cent. with a deposit of 20 lb. per kilowatt-hour. The current density used was 16.7 amp. per square foot. Anodes were spaced 4½ in. from center to center. Starting sheets were cast by allowing molten lead to flow down an inclined cast-iron plate. Electrolytic lead refining must be made to pay through its byproducts, particularly bismuth, and it seems questionable whether it can be adapted to a low-bismuth bullion.

TYPICAL	ELECTROLYTIC	LEAD	REFINERY	MATERIALS
	THROTHOLIST	البحديديد	TAMATIN TO T	MINIMA

	Pb, per cent.	Ag, os. per ton	Au, os. per ton	Bi, per cent.	Cu, per cent.	As, per cent.	Sb, per cent.	Te, per cent.
Anodes Slimes Electrolyte. Refined lead Slag, slimes	8.32			4.81	0.065 1.45 0.00049 0.001		22.75	0.011 0.45 ¹
	37.50	313.0	0.72	1.68	2.65	6.75	22.92	••••

Electrolytic Production of Metals

Aluminum—from fused cryolite bath containing Al₂O₃ in solution (cryolite 36 per cent.; AlF₁ 44; CaF₂ 20). The specific gravity of a saturated solution of Al₂O₃ in cryolite is 2.35, that of molten aluminum is 2.54. The bath must be fluid at 900° to 950°C. Cryolite melts at 1000°C., but with 10 per cent. Al₂O₃ present it is 930°C., and with 20 per cent. 880°C.; 25 per cent. saturates the solution. The current density is about 700 amp. per square foot of cathode section, potential (theoretical, 2.8 volts) 7.5–8.5 volts. Anodes are carbon blocks, cathode the carbon lining of the furnace. Power consumption 1400 e.h.p. per metric ton of metal per 24 hours. Also prepared by electrolyzing a double sulphide of aluminum and sodium. Potential about 5 volts. The alumina for electrolysis should carry a minimum of 98 per cent. Al₂O₃.

¹ These slimes were largely produced from the anodes just above.

² Carries also 11.78 per cent. H₂SiFe; 0.36 per cent. HF; 0.28 per cent.
Zn; 0.44 per cent Sn

Some	TYPICAL	BAUXITES1
------	---------	-----------

	New South Wales	Italian	French	French	German
Al ₂ O ₃		47.44-57.00		4320	55.61
Fe_2O_3		25.98–36.77		7.25	7.17
SiO_2	0.16	2.33 - 4.06	5.78	34.40	4.42
TiO ₂	4.75	1.17-2.86			
CaO		 	 		
MgO	0.37	 	l	<i>.</i>	 ••••••••••
KNaO			·		
Volatile	23.45			15.15	32.33

Antimony—may be recovered by electrolysis from the sulphantimonite. The anodes are lead plates, the cathodes and tanks are iron. Current density is 10 to 15 amp. per square foot at start, later 4 to 5 amp. per square foot. The voltage is about 2. The metal is always contaminated with iron when produced in this way. Betts also proposes electrolysis of the fluoride in solution carrying an excess of hydrofluoric acid.

Beryllium—from the fused double fluoride of sodium and

beryllium.

Bismuth—is refined electrolytically in BiCl₃ solution carrying an excess of free hydrochloric acid. Current density, 15-30 amp. per square foot. Anodes, argentiferous and auriferous bismuth; cathodes, pure bismuth; porcelain tanks.

Cadmium—obtained by the electrolysis of CdCl₂ or CdSO₄ solutions. Current density, 6 to 15 amp. per square foot; e.m.f.; 0.045 volts. Cathodes are cadmium sheets, anodes are

of crude cadmium.

Calcium—from fused calcium chloride or iodide. Current density must exceed 500,000 amp. per square meter. Electrolyte near cathode must be at lowest possible temperature. Cell resistance, 12 volts.

Cerium—from the fused chloride, which is traversed by an alternating current to keep it fused and decomposed by direct

nirrent

Chromium—according to Borchers, may be produced by electrolysis of a CrCl₂ solution containing 13–14 oz. of chromium per gallon. The anodes are carbon, the cathodes platinum foil. The current density must be from 85 to 170 amp. per square foot. At 70 amp. per square foot the metal contains perceptible amounts of CrO, and with 8 amp. per square foot, only CrO is deposited. The temperature must not exceed 122°F. G. Glaser has compiled the following table regarding the behavior of chromium during electrolysis:

¹ Schnabel, "Handbook of Metallurgy." The Macmillan Co.

Current density, amp. per sq. ft.	Deposit	Current efficiency
8,36	Chromo-chromic oxide	
16.7	At first metal, then chromo-chromic oxide	
33.4	Metal, mixed with chromo-chromic oxide	
41.7	Thin metallic layer, on which oxide afterward	
	deposits	5.4
66 .8	Metal, with a small quantity of oxide	
84.5	Pure metal	38.4
127.3	Pure metal, with a growth of crystals	38.0
169.0	Pure metal, for the most part crystallized	38.6

The effect of solution concentration was also studied:

Grams Cr per liter of solution	Deposit	Current efficiency
210 184 158 135 105 79 53 26	Metallic powder, mixed with chloride of chromium Same. Pure metal. Pure metal. Pure metal. At first metal, then chromo-chromic oxide. Chromo-chromic oxide and hydrogen. Trace of chromo-chromic oxide, brisk evolution of hydrogen.	56.6 49.0 38.4

Copper—obtained by the electrolysis of copper-sulphate solutions carrying free sulphuric acid, using copper cathodes and anodes. Current density about 12 to 15 amp. per square foot, e.m.f. 0.34 to 0.44 volt. Temperature of solution about 114°F. Ag, Au, Pb, Se, Te go quantitatively to the slime; Bi, As, and Sb, chiefly to the slime; Fe Ni, Co into solution, except the nickel be present in the anode as NiO.

Gold¹—from gold-chloride solution carrying 25-30 oz. of gold and 25-30 oz. free HCl (sp. gr. 1.19) per cubic foot. anode is the unrefined gold, the cathode is a pure sheet. anodes carry lead, some H₂SO₄ is added. Current density about 100 amp. per square foot, potential 1 volt, temperature 60-70°C. Tanks—stone or porcelain. (Wohlwill process.) Pt stays in the electrolyte, Ag slimes as chloride.

Iron—may be obtained by electrolysis of the sulphate. Anodes are pig iron, the cathodes are pure metal. Current density about 110 amp. per square meter, electrolyte contains 10 per cent. FeSO₄·7H₂O and 5 per cent. (NH₄)₂SO₄. perature carried at about 30°C. Voltage drop across tank about This, however, gives a metal carrying a trace 0.3 to 0.9 volts. of sulphur. While a chloride electrolyte is free from this objection, iron produced with such an electrolyte corrodes readily because of occluded chlorine. In either case there is a large amount of occluded hydrogen. (See also pp. 311 and 592.)

Lead—can be produced by electrolysis in a solution of lead fluosilicate carrying free hydrofluosilicic acid and a little gelatin. Anodes, base bullion; cathodes, pure lead sheets. Temperature of solution, about 87°F. cathode density, 10–12 amp. per square foot.; potential, about 0.3 volts; tank, wooden.

Lithium—from fused mixtures of LiCl with an alkalineearth ehloride. From a solution of lithium chloride in pyridine.

20-30 amp. per square centimeter, 14 volts.

Magnesium—from fused magnesium chloride, from fused K-Mg or Na-Mg chlorides. Current density, 1000 amp. per square meter; cell voltage, 1 to 8; anode, carbon in porcelain envelope. Do not raise temperature of bath much above melting point of the magnesium.

Potassium—from fused mixtures of KCl with an alkaline-

earth chloride. General process same as sodium.

Silver—(Moebius and Thum processes) recovered by electrolysis of a nitrate solution carrying about 0.1 per cent. free HNO₂, 5.0 per cent. Ag, and some copper. The cathode is either silver (Moebius process), or carbon (Thum process). The anode is the doré. The current density is 30-40 amp. per square foot; the e.m.f. is 1.4-1.5 volts; the tanks are usually porcelain. The Cu in the anodes dissolves; Pt and Au stay in the slime.

SOLUBILITY	ΩF	SILVER	CHIORIDE ¹
COMODIMIA	UF	DILITER	

Salt	Strength of solution, per cent.	Temperature, deg. C.	Silver chloride dissolved per liter, grams	Silver per liter, grams
KCl	24.95	19.6	0.914	0.688
NaCl	25.96	19.6	1.270	0.956
NH ₄ Cl	28.45	30	3.673	2.764
CaCl ₂	41.26	30	8.350	6.283
$BaCl_2 \dots$	27.32	30	0.741	0.558
MgCl ₂	36 . 35	30	7.095	5.339
FeCl ₂	30.70	20	2.395	1.802
FeCl ₃	37.48	21.4	0.085	0.064
$MnCl_2$	43.85	30	2.958	2.226
ZnCl ₂	53.34	30	0.215	0.162
CuCl ₂	44.48	30	0.833	0.627
PbCl ₂	0.99	30	<i>.</i>	

The above table is by H. C. Hahn and W. M. Curtis. According to Vogel and Bernhart, the solubilities in grams of silver chloride per liter of solution are as follows: KCl, 0.472; NaCl, 0.950; NH₄Cl, 1.575; CaCl₂, 0.930; BaCl₂, 0.143; SrCl₂, 0.884; MgCl₂, 1.710. They also state that it is insoluble in the chlorides of tin, mercury, copper, zinc, cadmium, nickel and cobalt. But some unpleasant experiences of my own

¹ Schnabel's "Handbook of Metallurgy," Vol. I. The Macmillan Co.

convince me that it is highly soluble in a mixture of cuprous

and cupric chlorides.

Sodium—from fused sodium hydroxide—Castner process Iron anode, carbon cathode. From fused sodium nitrate-Darling's process—Iron melting vessel serving as anode. Magnesia diaphragm, carbon cathode. Cell resistance 15 volts. From fused sodium chloride. Current density over 5000 amp. per square meter.

Strontium-from fused strontium chloride. General con-

ditions like those of calcium production.

Tin—the electrolysis of tin commercially is confined to the detinning of old tin-plate, chiefly by the caustic-soda process. The cathodes are iron, the anodes are the tin scrap, packed in wooden baskets. Electrolyte contains about 9 per cent. NaOH, which is recausticized from time to time by Ca(OH)₂. tank potential is about 1.5 volts, the current density 8-12 amp. per square foot and the temperature 160°F. and up. Alkaline sulpho-stannates have also been proposed as electrolytes.

The best electrolytic tin deposits are probably obtained from a stannous-ammonium oxalate bath with peptone as an addition agent. A good composition, according to Frank C. Mathers and Barrett W. Cockrum ("Trans." Am. Electrochem. Soc., Washington, D. C., meeting) is: 5 per cent. stannous oxalate, 6 per cent. ammonium oxalate, 1.5 per cent. oxalic acid and 0.25 per cent. peptone. The stannous oxalate may be made by precipitating a solution of stannous chloride with The solution must be stirred at intervals and is run at 3.6 amp. per sq. ft. at room temperature.

Uranium—from fused uranium-sodium chloride; cell re-

sistance, 8 to 10 volts.

Zinc-The Brunner, Mond & Co. works at Winnington is said to operate as follows: The electrolyte is ZnCl₂ with 0.08 to 0.12 per cent. free HCl, the cathodes are rotating zinc plates, and the anodes are carbon. The current density is 10 amp. per square foot and the e.m.f. of the cell is 3.3. to 3.8 volts. apparatus is complicated, as there must be piping for carrying off the chlorine generated, which is then used for making bleaching-powder. The solution tends to become basic after prolonged electrolysis and additional acid must be added.

Since the outbreak of the war a great deal has been done to solve the general problem of the electrolytic production of zinc. The following is understood to be the outcome of the experiments, but accurate data are hard to obtain. At Anaconda, Mont., and Trail, B. C., the ore is leached with the spent electrolyte which contains free sulphuric acid until almost neutral. The solution is then freed from impurities with zinc oxide and electrolyzed, using lead anodes. The process appears to be what every experimenter has tried for some years, and success is, apparently, a matter of close attention to details of current density, concentration, etc.

In the process as conducted by Keating at Bully Hill, Calif.,

lime is used to precipitate zinc hydroxide and calcium sulphate from the solution of the zinc sulphate. This precipitate is suspended in the zinc sulphate liquor of the electrolytic cell and as fast as sulphuric acid forms it is neutralized by the zinc hydrate.

In the Mammoth Copper Co.'s experiments at Palo Alto., Calif., a sponge-lead cathode is used, the sulphuric acid formed by electrolysis forming lead sulphate, which can be decomposed later by reversing the current. The material used is said to be the result of leaching the baghouse dusts with sulphuric acid.

Anaconda Electrolytic Zinc Process.—The following is a highly condensed description of the course of treatment as originally

designed:

The ore being treated assayed as follows: Zn, 17 per cent.; S, 14 per cent.; Pb, 2 per cent.; Cu, 0.5 per cent.; Fe, 6 per cent.; insol., 40 per cent.; and 3 oz. of Ag per ton. The zinc was present as the sulphide. The ore, all of which will pass through a 60 sieve, is roasted in a McDougall roaster, 6 hearth and 20 ft. diameter; 1 per cent. MnO2 is added occasionally, and is said to assist the oxidation of the iron. The roasting temperature is about 1350°F. Too high a temperature gives rise to the production of ferrite of zinc, which is insoluble in acid. About 20 tons of ore are roasted per day down to between 1 and 2 per The zinc in the ore after roasting is in the forms of sulphate, oxide, ferrite, and sulphide, and 25 per cent. of the zinc is frequently soluble in water. The solution is effected in red-wood agitating tanks, 12 ft. diameter and 10 ft. deep, each fitted with a wooden shaft and stirrer supported by a bearing at the top of the tank. Before discharge the acid solution is neutralized by crushed lime rock. The time of agitation is 2 hours, with sulphuric acid of 6 per cent. strength at a temperature of 60°C. Two hours are occupied in emptying the tank, so that the total time of treatment in the tank is 4 hours. The neutral pulp from the agitator is run into the first of two sets of flotation machines (M.S. Type), used as mixers and aërators, and zinc dust is added at the rate of about 10 lb. per ton of ore to precipitate copper. The iron, or most of it, has been precipitated by the lime rock as ferric hydroxide in a well coagulated form. The pulp issues from the M.S. machines with a consistency of about 2:1, and is first of all thickened in a square tank in which are suspended filter leaves about 6 ft. by 8 ft. The clear solution from these leaves is added to that obtained later from the OLIVER filter, and the thickened material is passed on to an Oliver filter, 10 ft. diameter and 12 ft. long. The clear solution from the Oliver filter, together with that from the filter leaves, then passes through the second set of M.S. machines, where it receives a further dose of zinc powder to eliminate all the copper. After this second zincing the solution is not filtered, but is transferred to the electrolytic solution tank. The copper is reduced in the first set of machines to 0.01 per cent., so that by the time the second treatment is finished it has been practically eliminated. It is essento the cells assays about 6 per cent. Zn, 0.1 to 0.3 per cent. Mn, a very little PbSO₄, and no acid. The rate of flow through the cells is 45 gal. per min., and the "tails" solution from the cells contains 3 per cent. Zn and 6 per cent. acid. This forms the leaching solution for the next ore charge. Too much sulphate in the roasted ore is to be avoided, because it gives rise to too much production of acid in the cells. The cells are made of wood, lined with pure lead. The anodes are pure lead plates 2 ft. wide; they dip into the electrolyte for about 3 ft. The cathodes are either aluminum plates or zinc starting sheets. The current density is 30 amp. per sq. ft. at a voltage of 4. Current efficiency = 80 to 90 per cent.; 1 h.p. day = 10 lb. zinc.

Electrolytic Zinc Refining

During the days of the great spread between the prices of brass special and prime Western spekter it was possible to make a profit by buying the latter and rolling anodes from it, which were then refined just as is electrolytic copper. However, as the zinc bubble subsided, it is understood that the profits of these companies did likewise, until they were forced to quit business.

Loss of Zinc in Brass Melting.—In some experiments carried on by H. M. Thornton and Harold Hartley (Amer. Inst. of Metals, September, 1916) it was found that in melting an 87.5:10:2.5 red brass twice, that the loss was 3,56 per cent. of the zinc contents. Pouring temperature was about 1090°C.

Iron Refining—Cowper Cowles Process

The electrolyte consists of ferrous chloride, cresol-sulphonic acid being used as an addition agent. Scrap iron is kept in the bath to insure its reduction and iron-oxide is suspended in it both to keep the bath neutralized and to polish the cathode deposit by friction. The unannealed deposit contains 394 volumes of hydrogen per volume of iron, while if the cathode is heated to a dull glow this is reduced to 1¾:1. The voltage is about 1.5 per cell, and the current density high, about 7 am. per sq. decimeter. (See also pp. 311 and 588.)

Carnotite Ore Treatment

According to Metaux et Alliages, the following is the treatment of carnotite ores in Colorado. The mechanical concentration of the carnotite, which is generally about 3 into 1, is made in Dorr classifiers. The chemical extraction following this may then be either by an acid or basic process. As an example of the first class is the Pleck-Haldane-White process which is as follows:

The crushed mineral is agitated with 15 to 20 per cent. of sulphuric acid, after which it is filtered. The insoluble residue is washed with dilute acid and again filtered, and to the filtrate enough acid is added to give a concentration of 15 to 20 per cent. This solution is then used for the first treatment of fresh

portions of ore. The first filtrate contains the vanadium and uranium, together with the copper and other impurities. is heated in contact with fresh portions of ore in order to neutralize the solution. (A part of the vanadium and uranium is deposited upon the ore in this process and enriches it. The mixture is filtered and the enriched material goes back to the first treatment.) The neutralized solution is treated with sulphur dioxide. The iron and vanadium are reduced to the ferris vanadate condition, the sulphur dioxide being transformed to sulphur trioxide, which combines with the water to form sulphuric acid. There is again added just enough of the original ore to neutralize this acid, the mixture being again filtered and the insoluble residue sent to the first treatment. To the filtrate is added enough powdered limestone to precipitate the vanadium, copper, and uranium, calcium sulphate being also formed. In order to precipitate these metals it is necessary to boil after adding the limestone. With this precipitate of vanadium, copper, uranium, and calcium sulphate are also thrown down basic sulphates and carbonates of iron. The mixture is then dried and sent to the works for extracting vanadium, uranium, and radium.

This process has the disadvantages that the final products still contain a large percentage of impurities, that the operations are tedious, and that much material is re-treated. However, it serves very well to make a preliminary concentration of the valuable materials in an inexpensive plant near the mines.

Basic Process.—The principle of this process consists in obtaining the vanadium in solution and the uranium in the form of an insoluble uranate. The crushed material is mixed with alkaline carbonates and hydrates and calcined. The frit is then pulverized and heated in an alkaline solution. The vanadium goes into solution, the uranium, with a very small amount of the vanadium and the insoluble gangue, remains undissolved. The filtrate containing the greater part of the vanadium is neutralized and the vanadium is then precipitated as a vanadate of iron, copper, or lead, which is then filtered dry. The vanadate thus obtained is usually treated either by the Goldschmidt aluminum process, or in the electric furnace.

Optical Pyrometers. (From "The Measurement of High Temperatures," The Engineer, vol. cxviii, No. 3078.)—In connection with the recent work on radiation pyrometers and their calibration, C. R. Darling says that it is of interest to recall

the views of Sir Robert Hadfield on the subject:

Measurement of temperature from a distance by means of radiation or optical pyrometers fails for two chief reasons: First, the temperature of the surface on which the instrument is sighted is lower than that of the interior, even in the case where no oxidation occurs and no slag is present. In practice the presence of oxide or slag in layers of varying thickness renders it impossible to establish any fixed relation between the temperature of the surface and the true internal temperature, and hence concordant results can not be obtained. Second, when

38

fumes are rising from the ladle, as is frequently the case with alloys, the radiations received by the instrument are seriously diminished, and the reading, even if otherwise reliable, would be too low on this account. These difficulties have been partially overcome by Whipple's modification of Ferr's radiation pyrometer described by the writer in the Engineer for June 13, 1913, in which the pyrometer is permanently mounted at the open end of a fire-clay tube so as to be focussed on the closed end, which is inserted in the molten metal. This method, while suitable for crucibles and small ladles, can not be applied to large masses, as the readings would be affected by the intense heat existing in the vicinity of the pyrometer. The solution of the problem, therefore, appears to lie in some suitable application of the thermo-electric or resistance methods of measuring high temperatures.

Recovery of Radium from the Olary Ores

Because of the general interest in the extraction of radium the following excerpts are given from S. Radcliff's description of the recovery of radium from the Olary (Australia) ores at the Radium Hill Co.'s plant at Sydney, N. S. W. (Min. and Eng. Review, Oct. 5, 1914).

The ore is dry crushed at the mine to pass a sieve of 20 holes to the linear inch, and is then concentrated magnetically; the concentrates, amounting to about 30 per cent. of the ore crushed,

being forwarded to Sydney for treatment.

The concentrates have the composition: CaO, 0.55 per cent.; PbO, 0.16; Fe₂O₈, 17.4; FeO, 16.9; MnO, tr.; thorium, cerium, lanthanum and didymium oxides, 3.27; Cr₂O₈, 0.85, U₂O₈,

1.6; V_2O_5 , 0.86; TiO_2 , 45.85 per cent.; SiO_2 , 12.70.

As the concentrates are insoluble in acids, a fusion process is necessary to effect the initial decomposition. The concentrates are mixed with three times their weight of salt cake (acid sulphate of soda) and fused in a reverberatory furnace of sufficient capacity to take 500 kilos of concentrates and 1500 of salt cake in a single charge. Three charges can be put through in 24 The fused product, crushed to 8 mesh, is fed, in small amounts at a time, into wooden vats filled with agitators. water is fed continuously into the vats at the bottom and an overflow is provided near the top. By suitably adjusting the conditions, it is possible to separate out on the bottoms of the vats a considerable amount of comparatively coarse material which is almost free from radium and uranium. The turbid liquid overflowing carries in suspension the radium, lead and barium as sulphates, together with a considerable amount of finely divided silica; while in solution we have the uranium rare earths, and part of the iron and acid earths contained in the

The coarse residues are removed from the vats daily, rewashed to free them from any undissolved fused product and

sent to the dump.

The overflow from the dissolving vats is pumped to large lead-lined settling tanks and allowed to stand all night. The "slimes" settle completely in 12 hours, and the clear liquid is drawn off daily and treated for the recovery of the uranium. The slimes which amount, when dried, to approximately 10 per cent. of the weight of the concentrates, are collected weekly and treated for the recovery of the radium as described below.

The further steps in the treatment process may conveniently

be described under two heads:

(a) The recovery of the uranium.(b) The recovery of the radium.

Recovery of the Uranium

The clear solution containing the uranium and much of the iron and other bases in the concentrates, together with a large amount of sodium salts, is fed into series of vats containing a measured excess of a mixture of carbonate and bicarbonate of

soda; and heated and agitated by means of steam jets. iron, with most of the other bases present, is precipitated, while the uranium goes into solution together with some of the rare The bulky iron precipitate is separated partly by settlement and partly by means of vacuum filters. It is difficult to handle and cannot be washed effectually; a portion of the uranium is therefore unavoidably discarded along with this precipitate. The uranium solution is made just acid with sulphuric acid, heated and the carbon dioxide expelled by a brisk current of air. The uranium is then precipitated by the addition of ammonia. The ammonium uranate is thickened somewhat in conical settling tanks and then further thickened to a pulp in a hydro-extractor. This pulp is dried and dehydrated in large muffles. The dehydrated product is broken up and washed repeatedly with hot water. This treatment removes the bulk of the sodium salts, and a product is obtained which on drying contains about 75 per cent. of U₈O₈. An analysis of this, together with that of the iron precipitate, is given below. Prior to analysis the iron hydroxide was twice dissolved and reprecipitated with ammonia to free it from the large amount of sodium salts present. The washed precipitate was dried, ignited and analyzed.

,	Uranium product	Iron precipitate
Insoluble matter Titanium dioxide		8.11
Ferric oxide		74.65
Uranoso-uranic oxide	16.6	2.7
Rare earths		7.36
Lead oxide	_	
Vanadic oxide		
Chromium oxide	•	5.81
Sodium salts	8.21	

Recovery of the Radium

The thickened insoluble residue or slime from the settling tank is mixed with half its dry weight of strong sulphuric acid and allowed to stand for several days. It is then washed, first by decantation and then on a vacuum filter, till the washings give only a very slight precipitate with barium chloride. The acid treatment and washing reduces the bulk of the slime considerably, removing large amounts of acid earths and iron salts. The washed slime in quantities of about 200 kilos, dry weight, is then boiled in a large steel boiler under pressure with an excess of a 20 per cent. solution of sodium car onate for two days, the solution being replaced once during the boiling. This treatment dissolves a large amount of silica, and converts much of the lead, radium, and barium sulphates to carbonates. The slime is then washed till the wash water gives no reaction for

sulphates; this takes 2 days for each lot of 200 kilos. The washed slime is then fed into a warm dilute solution of hydrochloric acid, agitated for a couple of hours, and allowed to settle all night. The clear solution is siphoned off and the lead, barium, and radium precipitated as sulphates. After washing once by decantation, the slime is again treated as above described. Two treatments suffice to extract most of the radium, but the slime is reserved for a further treatment, if necessary. The plant as at present arranged can treat the slime from 10 tons of concentrates per week. The weekly yield of crude sulphate is about 12 kilos.

A number of experiments, both in the laboratory and on the working scale were made to see if the sulphates in the slime could be reduced by heating the material with carbonaceous substances, or else in a current of some reducing gas, but the

results so far have not been encouraging.

The treatment of the crude sulphate is now carried out as follows, not as in the paper read by the author before the Royal Society of New South Wales in 1913: The crude sulphate is dried and fused with three times its weight of caustic soda in an iron pot. The melt is poured, cooled, and digested with hot water. Most of the lead goes into solution. The insoluble residue is washed till free from soluble sulphates, and then digested in a rotating boiler under a steam pressure of about 60 lb. This converts the bulk of the sulphates of barium, radium and lead to carbonates. The carbonates are well washed on a filter and dissolved in hydrochloric acid. The solution is taken to dryness to remove any colloidal silica, and the residue is taken up with water and a little HCl. In addition to barium and radium chlorides, small amounts of iron and lead chlorides, together with considerable quantities of barium, lanthanum, didymium, and thorium chlorides are present. This solution is now saturated with hydrogen chloride gas; the barium and radium are precipitated quantitatively as chlorides, almost free from the other substances present. The chlorides are filtered off, dried, dissolved in water, and purified from the small amounts of second and third group elements in the ordinary way. They are finally precipitated as carbonates by means of pure Na₂CO₃, and the carbonates dissolved in HCl. This solution is now ready for fractional crystallization for the recovery of the radium.

The economic success of the process depends on the fact that it is possible to decompose the uranium minerals without bringing the whole ore complex into solution, and that comparatively small amounts of reagents are required to effect this. The tailings sent to the dump, amounting to about 50 per cent. of the material smelted, are almost free from radium and uranium, and appear to consist mainly of unaltered rutile. The radioactive slimes amount to about 1 ton from every 10 tons of concentrates, and are one-fifth of the weight of the tailings. As the alpha ray activity of the slimes is thirty times that of the tailings, it appears that the slimes carry over 80 per cent. of the

radium originally present in the concentrates. That is, the initial fusion of the concentrates enables a great concentration of the radium to be made by mechanical means before continuing the chemical treatment.

The rare earths in the concentrates distribute themselves in the course of the iron hydroxides carrying 7.36 per cent. rare earths, the uranium product containing 1.57 per cent. and the crude sulphates. The rare earths extracted from the iron hydroxide precipitate are only very feebly radioactive. The activity does not increase with time, and is due to the presence of 0.06 per cent. of thorium oxide, with its attendant ionium. The earths extracted from the uranium product are also only very feebly active. The rare earths carried down with the crude sulphate contain a considerable proportion of the thorium in the ore, and appear also to carry most of the actinium. This is to be expected, as it is well known that actinium can be extracted from a solution by precipitating barium sulphate in it. A thorium-ionium preparation worked up from the earths in the crude sulphate has an activity several hundred times as great as that of U₂Os.

The rare-earth mixture, containing about 3 per cent. of rare earths in addition to the constituents enumerated, is fused in an iron crucible with excess of sodium hydroxide containing some sodium carbonate, the melt extracted repeatedly with hot water, the insoluble residue digested with excess of sodium carbonate under a steam pressure of 90 lb., the carbonate residue washed, treated with dilute hydrochloric acid, the solution evaporated to dryness, the residue treated with water, the silica filtered off, and the solution saturated with hydrochloric acid gas (to precipitate the radium and barium) and filtered. The filtrate, containing the actiniferous rare earths, is evaporated to dryness and the residue further treated to separate actinium. *Ionum* appears to be chemically inseparable from thorium, so that by extracting and purifying the latter by any of the well-known methods an active ionium product is obtained.

DUST AND FUME CONDENSATION

The problem of dust catching is one of reducing the speed of the gas sufficiently. James Douglas, in writing of the Copper Queen, says that all true dust would settle from a velocity of 2½ ft. per second in a chamber 125 ft. long, which rate of settlement can be materially increased by wire screens placed across the direction of flow. Later it was understood that the rate adopted was 5 ft. per second. Hence dust settlement reduces itself to a question of large chambers and of temperature reduction, which reduces volume and hence speed. The reduction of temperature can best be achieved by thin-walled steel flues—often, as at Mammoth, by passing the gas through a great number of parallel steel pipes. These pipes may or may not be cooled by a water spray. Another method is to make the top of a brick flue out of a series of cast-iron pans which are set step-fashion,

so that each overflows into the next, the feed being just sufficient

to equal the combined evaporation from all the pans.

The use of baffles and tortuous windings in the flues has largely been given up, as it is usually conceded that these act more as stirrers than settlers. However, settlement is helped by plates hung so that they are parallel to the travel of the gas (FREUDENBERG plates), or by wires across the travel (Roesing's wires).

A stack is of practically no value as a dust settler. It may be needed to give the necessary draft through the flues, or to discharge the gas so high that it will be diluted enough not to be unendurable by the time it reaches the ground, but that is about all. When a dust particle starts up a stack it usually emerges on top. The Wislicenus stack consists of a large number of radial openings near the top of the stack. The wind enters through these and quickly dilutes the effluent.

The ferrous metallurgist uses the centrifugal gas washer (a test of a Thiessen washer is given in the succeeding pages) but it seems doubtful whether they would have any effect on the

lead- or copper-smelter's fume.

For fume condensation-the most successful treatment seems to be the Cottrell system of electrostatic discharge, described at more length below, filtration through bags, or precipitation by thoroughly atomized water (Schütte-Koerting system). Scrubbers in which the gas is allowed to bubble through water amount to very little, although their efficiency can be raised, usually, by oils or acids in the water. Figures on baghouse work are given on p. 565. While a baghouse should pay in lead smelting or on silver furnaces, it probably does it only indirectly in copper work—by keeping the smoke farmers quiet.

Gas control must be by chemical means, except that SO₃ is very easily condensed by the Cottrell system. Sulphur dioxide and trioxide are controlled completely at the Ashio mines, Japan, by passing all the effluent gases through lime water. The Sprague system adds zinc oxide to the flue gases and filters out the zinc salts in the baghouse. The Hall process aims to reduce the sulphur oxides to sulphur as formed in the furnaces using hydrocarbon vapors as the reducing agent. Young's thiogen process aims at the reduction of the

sulphur vapors in the flues by hydrocarbon gases.

Electrostatic Precipitation (Cottrell Process)

This is best performed in tubes in which the tube forms one electrode and a wire placed concentrically with it forms the other. The discharge should not be one produced by an alternating current, but should be a silent discharge with the wire preferably the negative anode. The breakdown voltage with most smoke is about 32,000. The presence of fine points due to hardened deposits, kinks in the wire, rough spots, etc., tends to localize the discharges from the wire, and even though there be many such points, the cleaning action of such discharges is

much below that of a uniform field around a straight wire (A. F. Nesbit, "Trans. A. I. E. E.," Third Midwinter Con-

vention, Feb. 17 to 19, 1915).

At the Hooker Electrochemical Co.'s Plant 30,000 cu. ft. of gas per minute is treated with a power consumption of 3 to 5 kw. At the Garfield, Utah, smeltery 200,000 cu. ft. of gas per minute is treated with an expenditure of 50 kw. The electrode spacing is 2½ in. and the potential is 50,000 volts. At Tooele, Utah, 20,000 cu. ft. of gas per minute requires less than 5 kw. Each of the two units contains 48 pipes 12 in. in diameter by 15 ft. long.

A full review and complete bibliography of this process is

given in in the Eng. and Min. Journ. of Feb. 26, 1916.

Thiogen Process

The thiogen process was devised by S. W. Young of Stanford University, in an attempt to eliminate sulphur gases from smeltery smoke. The process contemplates passing a mixture of the sulphur-bearing gases and a hydrocarbon reducing agent of the ethylene series over a catalyst of calcium sulphide. The reactions are:

$$CaS + SO_2 = 2CaSO_3 + 3S$$

 $2CaSO_3 + C_2H_4 = 4CaS + 2CO_2 + 2H_2O_3$

In practice, when a mixture of sulphur dioxide and hydrocarbon vapor pass together over a mixture of calcium sulphide and calcium sulphite, the reactions proceed simultaneously. The hydrocarbon gas is generated from fuel oil. The process has been tried at the Penn Smelting Works, Campo Seco, Cal., but the catalyst poisons easily and it does not appear that it is yet a commercial process. (See Eng. and Min. Journ., Feb. 15, 1913.)

Hall Process

An invention of E. J. Hall, by which sulphur-bearing gases were to be treated immediately after their formation with a reducing gas containing some hydrocarbons. Elemental sulphur was to be set free, which was to be recovered in a centrifugal scrubber. The process was tried at the Balaklala smeltery in California, but is understood to have given trouble through the formation of allyl compounds that rendered the neighborhood extremely offensive, and through the fact that the washers did not do what was expected of them. (See Eng. and Min. Journ., July 5, 1913, for a fuller account of the theory of the process.)

Bag-house Data

Some data were given by Anton Eilers, before the International Congress of Applied Chemistry in 1912, concerning bag houses of the American Smelting & Refining Co. The Murray, Utah, plant treats furnace charges low in lead (10-12 per cent.) and the precious metals. They are wet and carry up to 4 per cent. of sulphur. Its total cost was \$127,195 including the cost of 4,032 cotton bags and the distributing flue, etc.

The building was $216\frac{1}{2} \times 90\frac{1}{2}$ ft., and was $51\frac{1}{2}$ ft. to the roof Stacks carried the fumes out of the building and it was necessary to place a lead-lined pan at a sufficient distance under the stack not to interfere with the draft, to catch the condensed moisture dripping from the stack sides, which otherwise drops on and eats away the bags. The bags are 18 in. in diameter and 30 ft. long, shaken from outside. The average life of cotton bags costing \$2.136 a piece, was 17 months, 11 days. They were replaced by woolen bags from the Buell Mfg. Co., St. Joseph, Mo., costing \$4.7185 apiece, which it is estimated last 4 years. Other bags were bought from the Laporte Woolen Mills, Laporte, Ind., at a cost of \$4.784. There are 570,012 sq. ft. of filtering surface for filtering 165,000 cu. ft. of gas per minute, but if one compartment was down, there were 2½ sq. ft. of filtering surface per cubic foot per minute. If over 24 in. of fume is allowed to accumulate in the cellars under the bags, spontaneous combustion begins. Therefore, when the cellar of any compartment contains 24 in. of dust, it is dampered off from the bags, hot coals thrown in on the dust, and the dust sintered by its own combustion. In this Murray bag house the following percentages of the metals charged in the furnaces were recovered: Lead, 1.269 per cent.; silver, 0.063 per cent.; gold. 0.049 per cent.: and copper, 0.0118 per cent. The opergold, 0.049 per cent.; and copper, 0.0118 per cent. The operating cost in 43% years was \$76,853; treatment charge on the material recovered was \$69,290, while the value of the metals recovered was \$152,691, showing an apparent gain of \$6,547, but if proper interest and amortization charges be placed against it, there is a net loss of \$58,746. These figures show that, taking the immediate financial outcome only, bag houses are not profitable in lead-smelting works, except where it is an object to stop smoke-suits.

Omaha Plant

This plant treats gases from converters treating leady copper mattes; from blast furnaces treating rich charges; and from zinc-oxide furnaces. The following facts are given for the converter bag house. The secret of long life for the bags is said to be thorough cooling of the gases before admission, and a good vacuum over the bags, drawing off the exhaust gases rapidly. The converter bag house has 68,000 cu. ft. in the flue; 67,000 cu. ft. in the cellar; 174,000 cu. ft. in the bag chamber; has 940 bags, 18 in. × 28 ft. long, having 124,000 sq. ft. of filtering area; treats the gases from converting about 45 tons of blister, or about 5,200,000 cu. ft. of gas which usually passes in 15 hr. out of the 24. The gas temperature at the bag house is 152°F. This bag house showed a profit of \$98,712 per year on a \$42,000 cost.

Some other miscellaneous bag-house data have been collected as follows:

Unwashed-wool bags have been found to be the best for filtering purposes because they last much longer than any other kind. Unwashed wool is wool which has not had the animal grease scoured out.

The method of neutralizing sulphurous gases at the United States lead smeltery at Bingham Junction is to pass the gases through steel flues exposed to the atmosphere in order to get cooling effect; then to add powdered lime to combine to form calcium sulphate. Zinc oxide is also very valuable for neutralizing these gases, but it is expensive. However, since the works have zinc concentrates to treat, these will be mixed with crushed coal or coke, and roasted in furnaces near the flues. The zinc-oxide fumes resulting will be conducted into the main flues after the lime has been added, about 100 ft. further on, so that the lime shall have had time to act. A considerable velocity of gases is required in order to keep the lime in suspension, 2200 ft. per minute, which was the velocity of the copper blast-furnace gases in the flues.

The gases should travel at least 100 ft. after the neutralizing

agents have been put in, in order to give them time to act.

Apart from their greater resistance to sulphuric acid, sulphuric anhydride, and selenium dioxide, wool bags are superior to cotton for filtering purposes because of the fine hairs lying on the surface, which arrest all the finest possible particles of the fume before they reach the actual pores of the filtering medium.

The bags at the United States lead plant are 34 ft. 6 in. long \times 18 in. in diameter. When tied in place they give a net filtering area 31 ft. \times 18 in. diameter, equal to 141 sq. ft. of filtering surface per bag. One sq. ft. of bag filter cloth is allowed for 0.7 cu. ft. of gas at 0°C. These bags weigh 7 to 8 lb. each and cost 45 cts. per linear yard. The freight on bags per pound is $2\frac{1}{2}$ cts. and the hanging cost is estimated at 15 cts. per bag. This makes the total cost per bag in place \$5.50. The mechanical shaking device installed in this bag house costs at the rate of \$2 per bag.

In the Mammoth bag-house experiments, 1 sq. ft. of filter cloth filtered 0.75 cu. ft. of gas at 0°C. under ½6- to ½-in. water pressure. There was no apparent deterioration of bags at 50° to 100°C. When temperature falls below 45° the bags become damp and permit the fume to escape. In dry weather, the temperature can be as low as 25°C. and the bags filter all right. The cotton bags used were of 50 mesh and the wool

bags of 20 mesh.

At the United States lead bag house the ideal temperature for lead blast-furnace gases is considered 70°F., and must not exceed 90°. The ideal temperature for roaster gases is 100°

and must not exceed 120°F.

At the United States lead bag house the blast-furnace bag dust is high in arsenic. This dust ignites of its own accord in the dust chamber basement and sinters to a sort of clinker which is treated in the arsenic plant. This clinker contains on an average 22 per cent. arsenic and 32 per cent. lead. This product goes to the Brunton furnace, 20 ft. diameter \times 4 ft. high, encased in brick, fired with coke, and with the hearth revolving once in about 9 min. The arsenic volatilizes and passes off as As_2O_3 . The lead sinters and is worked off the

hearth into hoppers by rabbles. This averages 40 per cent. lead and 9 per cent. arsenic. The As₂O₃ fume discharges into brick settling chambers $200 \times 20 \times 10$ ft. high for the first 50 ft., and 8 ft. high the rest of the length. At intervals of 8 ft. in this chamber are baffle walls to make the gases zigzag and deposit acid on the walls. The product from this chamber averages 97 to 99 per cent. arsenic and is further refined in a reverberatory furnace 25 ft. × 15 ft. × 6 ft., coke fired. This chamber is kept at 500° at 30 ft., 200° at 100 ft., and 120° at 175 ft. from the furnace. If the end chamber gets too hot the acid goes off and is lost. This product is crystalline and has to be ground for the market. It assays 99.87 per cent. pure and is much better than the foreign article.

In installing any bag house the quantity of gases and the temperatures will be known. It is required to determine the amount of cooling surface necessary to reduce this temperature to one which would not injure the bags, and then to determine the number of bags required to filter this amount of gas. The length of the cooling pipes is more or less fixed by the contour of the ground, and the available sites for the bag house. The sizes of the pipes are determined by the quantity of the gas flowing.

Experiments in radiation and conduction through No. 8 steel plate show that the rate of heat transmission is equal to 0.042 B.t.u. per minute per square foot of cooling surface per degree difference between temperature of gas and external air. The weight of this gas may be taken at 0.08 lb. per cubic feet at 0°C., and its specific heat at 0.2375.

A typical baghouse fume is Pb, 52.5 per cent.; Zn, 3; S, 5.4;

As, 14.2; Sb, 1.6.

Chimneys¹

The velocity of discharge of a gas from a chimney is as follows:

$$V = \sqrt{2gh\left(1 - \frac{t'}{t''}\right)}$$

where V =Velocity in feet per second.

g = Acceleration due to gravity. h = Height of chimney in feet.

t' = Absolute temperature of external air. t'' = Absolute temperature of the hot gas.

Since the velocity varies as the square root of the height, high chimneys do not pay. Indefinite increase in temperature of the exhaust gas is not an advantage, either, for although the velocity increases with increased temperature, the increase in volume The maximum results are obtained at 273°C. offsets this. over outside air.

Draught power of a chimney in inches of water is:

$$d = h \left(\frac{7.64}{t'} - \frac{7.95}{t''} \right)$$

1 W. R. INGALLS, "Metallurgy of Zinc and Cadmium."

Copper Leaching

In general, leaching processes fall into 12 distinct groups: (1) Oxidation of sulphides in the ore with formation of watersoluble sulphates. This may be slow, going on at ordinary temperatures; or a quick sulphatizing roast. This latter, in turn, may be either an oxidation of sulphides already present in the ore, or with addition of pyrite material, such as was tried in the Shannon Copper Co.'s experiments. However, owing to the formation of basic compounds, the products of the sulphatizing roast must ordinarily be treated with dilute sulphuric-acid solution, so that this process grades into: (2) Leaching of oxidized ores or calcined sulphides with sulphuric acid, in which category come the successful operations of the Anaconda Copper Mining Co., the Chile Exploration Co.'s plant at Chuquicamata, the New Cornelia Copper Co. at Ajo, Ariz., the Arizona Copper Co.'s leaching plant at Clifton, and the Butte-Duluth and Steptoe plants. Somewhat akin to these is: (3) The use of soluble persulphates, of which iron is the only practical example, as a solvent. The Siemens & Halske process is the classic example of this:

$$Cu_2S + 2Fe_2(SO_4)_3 = 2CuSO_4 + 4FeSO_4 + S$$

 $CuO + Fe(SO_4)_3 = CuSO_4 + Fe_2(SO_4)_2O$

(4) Closely allied to (2) is the process used at Stadtberge and Linz, Germany, in which oxidized ores were treated with sulphur dioxide and nitrous gases. Intermediate between two main groups of sulphate and chloride leaching stands: (5) the Dötsch process, used at Rio Tinto, Spain. In this process, ferric sulphate and salt are the reagents, the equations being essentially:

$$CuS + Fe2Cl6 = 2FeCl2 + CuCl2 + S$$

$$Cu2S + Fe2Cl6 = 2FeCl2 + Cu2Cl2 + S$$

The liquor is regenerated, after precipitation of the copper, by running it down through chlorine towers, the gas being produced by heating salt and ferrous sulphate in an oxidizing atmosphere in reverberatories:

$$2\text{FeSO}_4 + 4\text{NaCl} + 3\text{O} = \text{Fe}_2\text{O}_3 + 2\text{Na}_2\text{SO}_4 + 4\text{Cl}$$

The Hunt-Douglas process also falls into the same class. Among the chloride-leaching processes the use of (6) hydro-chloric acid has been proposed but does not seem to be in commercial use anywhere at present. (7) Höpfner uses cupric chloride:

$$CuCl_2 + CuS = Cu_2Cl_2 + S$$

while the use of ferrous chloride is theoretically attractive:

$$3CuO + 2FeCl2 = Fe2O3 + CuCl2 + Cu2Cl2$$
$$3CuCO3 + 2FeCl2 = Fe2O3 + Cu2Cl2 + CuCl2 + 3CO2$$

Practically, however, the reactions are slow, precipitation of the copper expensive, and regeneration of the "ic" salts incomplete. (8) The Longmaid-Henderson process first calcined the ores, then roasted with abraumsalz, a mixture of sodium, potassium, magnesium and calcium chlorides. In an absolutely different class of reagents come: (9) Ammonium carbonate or (10) ammonia. The great difficulty with these processes has been the loss of the reagents by volatilization, but the ammonialeaching process is now to be given a thorough trial at Lake Linden, Mich., under the auspices of the Calumet & Hecla Company. (11) Last is the theoretically beautiful leaching with sodium thiosulphate, which appears to be a practical failure through the ready decomposition of the reagent and the inhibitory effects of calcium compounds. (12) Leaching with nitric acid is to be tried by the Nevada-Douglas Copper Co. at Ludwig, Nev.

Any review of leaching would be incomplete without some reference to the ingeniously worked out Bradley process.1 The ore was carefully roasted to a sulphate and most of the iron was converted into insoluble ferric oxide. This must be done at temperatures between 450°C, and 550°C. The roasted ore was then brought into association with an excess of calciumchloride solution in a reaction drum at about a temperature of 100°C. Cupric chloride was produced by the reaction between the copper sulphate and the calcium chloride, while any ferric sulphate in the roasted product reacts with the calcium chloride to produce ferric chloride. The calcium sulphate from both these reactions is of course insoluble and is separated by filtration in the succeeding step.

From this solution the iron and alumina was precipitated by cupric oxide, hydrate, or calcium carbonate, which carries down some copper. This precipitate was therefore returned to the sulphatizing-roasting process, in which the bulk of the iron and alumina were rendered insoluble, while the copper was

converted into soluble copper sulphate.

The solution from which the iron and alumina had been removed and which contained the bulk of the copper was run into a second tank in which copper was precipitated by calcium carbonate as oxide of copper. The precipitate was filtered off and the copper recovered, while the calcium chloride was regenerated for use on further quantities of ore. There were also modifications for recovery of the silver, gold and zinc in the ore.

ently its own chemical complications caused its failure.

In the consideration of any leaching process the first factor is the character of the ore. Thus, an ore containing large amounts of calcium carbonate obviously cannot be successfully leached with any free-acid reagents. The same would equally apply to ores containing large amounts of soluble alkalies, magnesia, alumina, etc. The leaching agent will be determined partly by the character of the ore and partly by its own cost. The reagent most generally available and cheapest is sulphuric acid. Ample wash water is a sine qua non, while the last great question is that of a precipitating agent. On this we are at once reduced to iron, sulphur dioxide under pressure, electrolysis and calcium carbonate or hydrate.

¹U. S. Pat. No. 1,011,502.

Scrap iron, after the floating supply of tin cans has been utilized is likely to be an expensive commodity. Using a fairly pure copper sulphate solution, the consumption of iron is likely to run from 1½ to 1½ lb. of iron per pound of copper produced. Where the solutions are high in chlorides, as in the Dötsch process at Rio Tinto, the consumption of iron is said to run as high as 2½ lb. of iron per pound of copper produced. However, I do not feel that the possibilities of sponge iron, i.e., iron produced by the reduction without fusion of ferric oxide, have by any means been exhausted, and that the great hope of chemical precipitation lies in this material.

Electrolysis looks fine on paper, like everything else connected with leaching. However, as ordinarily conducted there will be constant trouble with the anodes, and only about 1 lb. of copper will be deposited per kilowatt-hour. According to theory, if sulphur dioxide can be introduced under proper conditions, the anode can be depolarized and the electrolytic cell made to be practically a primary battery. Working along these lines Lawrence Addicks claims to have obtained a deposit of 2½ lb. of copper per kilowatt-hour. But it is by no means certain that high enough current densities can be used when this efficiency is being obtained to make the process a com-

However, the factors of solution and precipitation will ordinarily be settled by purely commercial considerations, i.e., some one solvent and some one precipitant will probably be the one that must be made to work if the process is to be successful. The question of water supply must be settled by the

proper locating of the works.

Other details on which experimental work will have more of a chance to pick and choose are such matters as fineness of crushing, upward or downward percolation, percolation vs. agitation, strength of lixiviant, the control of impurities in the solution, both as to their control when there, and preventing them going into solution, the slime problem, adsorption of copper by the ore and the proper amount of wash water. This will probably seem a very summary dismissal of the leaching problem. So it is. The process has not arrived at the stage of having constants or published working costs and conditions.

Precipitation of Silver from Cyanide Solution

Precipitation from cyanide solution is by deposition of the dissolved metal upon zinc, either in the form of shavings or dust, or upon aluminum in the form of dust, or by electrolysis. Zinc dust is at present the most usual precipitant, although aluminum has some advantages, in that it does not form any cyanogen compound. Electrolysis has been a popular process, but at the present time it is considered too expensive for general use. One ounce of silver requires about one ounce of zinc or one-third of an ounce of aluminum for its precipitation.

¹ Eng. and Min. Journ., Jan. 9, 1915.

Sulphur-sand Cement¹

Sulphur-sand cement is composed of 1 part sulphur and 1.4 parts quartz sand ground to pass at least a 60-mesh screen. The mixture is heated to about 150°C. when it flows nicely and is sufficiently above the melting point of sulphur, 114°C., to prevent sudden chilling. The fact that sulphur begins to thicken above 156°C. and becomes so viscid that it will not flow at 180°C. must be borne in mind or there will be difficulty in working the cement. This is possibly the most satsifactory general cement available for low temperature work. It is readily handled and remarkably strong, has a tenacious bond is free from cracking and inert to most solutions. It will be found valuable for large-scale work, as well as in the laboratory. It was developed by Charles S. Bradley for use in his copperleaching process.

SizES AND CAPACITIES OF BULLION MOULDS²

, I ₁	nside measur	e	Capacity,	9:1	Weight
Length, inches	Width, inches	Depth, inches	gold, Troy os.	Silver, Troy oz.	of mould, lb.
1 11/2 21/4 33/8 31/2 4 1/4 41/2 5 1/8 5 1/2 5 1/2 5 1/2 6 3/4 7 1/2 8 9 9 1/2 9 1/2 10 10 1/2 11 11 11 12	5/8 1 1/3/8 1	1234 1 18 34 14 4 4 4 4 12 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3	4 10 25 50 95 100 136 180 244 250 295 365 375 550 620 730 910 1015 1285 1448 1470 1650 1830 2200 2750	2 5 12 25 50 56 76 100 134 140 166 200 208 300 340 400 500 600 700 800 810 900 1000 1200 1500	1 1 1 3 6 7 9 10 10 10 11 12 13 15 19 28 35 36 40 41 42 55 65 72 76

¹ E. J. Hall, Eng. and Min., Journ., July 17, 1915. ² As made by Fraser & Chalmers.

Briquetting

For the purpose of agglomerating flue dusts and fine ores there are a number of binders and methods. Among the binders may be mentioned cement, concentrator slime, milk of lime, molasses refuse (which usually leads to a convention of flies assembling from all the neighboring states), ferric- or ferrous-sulphate solutions, magnesium- or calcium-chloride solution (the use of 5 to 10 per cent. of magnesium- or calcium-chloride solution, equivalent to 0.25 to 2 per cent. of MgCl₂ or CaCl₃, followed by compression, constitutes the patented Schumacher process), and various asphaltic and tarry residues.

Of the various methods used with these binders may be mentioned hand-moulding, brick-press moulding (square form), round briquettes (Chisholm-Boyd-White machine), briquettes cut from continuous stream (Chamber's brick machine), the use of bags, and agglomeration in Huntington-Heberlein pots or Dwight-Lloyd roasters for lead ores, and on Dwight-Lloyd machines or in cement kilns for flotation concentrates.

For metallic chips the Ronay process is probably best.

This method is one for briquetting metallic chips without a binder. The divided metal particles are subjected in a mould to pressures of about 30,000 lb. per square inch. The briquette is allowed to remain under pressure a sufficient time to expel all the air and moisture, having been previously freed from dust

and dirt.

A general résumé of the subject of briquetting for iron-blast furnace work is abstracted by the Journal of the Society of Chemical Industry, Oct. 30, 1915, from Le Génie Civil, 1913, p. 306, and Revue de Metallurgie, 1915, p. 138. To be serviceable in a blast furnace, briquettes should satisfy the following tests: (1) fall from a height of 3 to 4 m. on to a metal plate without being reduced to powder, and withstand a pressure of about 140 kg. per square centimeter; (2) withstand a temperature of 900°C. without being reduced to powder; (3) stand in water for some time without softening; (4) withstand steam at 150°C. without being reduced to powder; (5) be sufficiently porous to absorb 12.5 to 16 per cent. by volume of water on being immersed for 25 minutes. The briquettes should be free from sulphur, arsenic, and other objectionable materials, and the cost of briquetting must not be greater than the difference in value of the ore in lump and as smalls.

Methods of Briquetting.—(1) (YEADON). 5 to 10 per cent. of slaked lime is added and the mixture made into a paste with water. Briquettes are formed under a pressure of 400 kilos per square centimeter and are placed in the open air to dry and harden. This requires at least 2 months. To avoid this delay steam under pressure is sometimes used, or about 10 per cent. of sawdust is added to the mixture and the briquettes are heated to 1200°-1400°C., when the wood carbonizes and the particles of ore frit together. (2) A mixture of equal parts of lime and sand is used as the agglomerant. (3) (SCHUMACHER). Fresh blast-furnace dust is briquetted with magnesium chloride

as binder. (4) Basic blast-furnace slag is used as the agglomerant for dust, hardening being effected by high-pressure steam. If the dust is deficient in lime, 4-4.5 per cent. of this material is added. (5) An intimate mixture of ore, limestone, and moistened cement is briquetted under a pressure of 400 kilos per square centimeter. The briquettes are serviceable after standing in the open air for 3 or 4 days. (6) (Weiss). Briquettes containing 5-6 per cent. of slaked lime are compressed at 300 kilos per square centimeter and subjected to the action of carbon dioxide under a pressure of 20 kilos per square centimeter, first in the cold and then hot. The treatment requires about 5 hours, after which the briquettes are serviceable. (RONAY). Blast-furnace dust or roasted pyrites is compressed hydraulically into briquettes, without the addition of binders, under a pressure of about 1000 kilos per square centimeter. (8) (GRÖNDAL). Impure ores are ground and concentrated in magnetic separators. The ore-mud is formed under small compression into briquettes, which are then passed on wagons of special construction through gas-fired tunnel furnaces. highest temperature reached is 1300°-1400°C., which causes the particles to frit together and drives off sulphur. The briquettes are of high quality.

Recent German Blast-furnace Practice.—A writer in Stahl und Eisen gives the following comparison of the space used per ton of pig iron in Germany 30 years ago with present practice. Our translation is taken from The Iron Age. The particulars

are the average of forty-three furnaces:

	20	Present practice		
Iron	30 years ago	Daily output	Per ton	
Foundry iron	4.5–5.5 3.5–4.5	Tons 185 165 350 \$\{\pmu 50\} 280	Cubic meters 2.89 2.22 1.34 1.28 1.10	

In a similar way the time required for the charge to work through the furnace has decreased considerably during the last 10 years. For basic-Bessemer iron it varies from 10 to 25 hours, the lower time for Westphalia and the higher for the Minette district. For open-hearth steel-making iron it is from 14 to 21 hours, for hematite 15 to 30 hours, and for foundry iron 16 to 27 hours. For spiegeleisen the time varies from 24 to 27 hours. For 80 per cent. ferro-manganese the time required is 20 hours with about 205 per cent. coke consumption, 18 hours with 230 per cent., and 12 hours with 260 per cent.; all for 90 tons daily output. For 12 per cent. ferro-silicon, with about 125 tons

daily output, it is about 14 hours with 215 per cent. coke consumption, and 12 hours with 225 per cent. The advantage of a wide throat that favors a uniform descent of the charge has found greater and greater recognition, so that diameters of over 5200 mm. (17 ft.) are not uncommon today, with a ratio to the diameter at the bosh line of 0.8, which makes the angle of the stack very steep. This angle is usually about 86 deg.; in particular, for furnaces making foundry iron it is 85 to 87 deg., for those making open-hearth steel-making iron, 811/2 to 861/2 deg., and for those making basic-Bessemer iron, 81 to 861/2 deg. With large outputs the bosh angle is 76 deg., although there are some exceptions. In particular, for furnaces making foundry iron the lowest case is 67 deg., the highest 77 deg.; for furnaces giving open-hearth steel-making iron the angle is 701/2 to 77 deg., and for those making basic-Bessemer iron, 71½ to 76½ deg. If the cross-section of the tuyères per ton of coke is compared for modern blast furnaces, considerable differences are found, and this is also true of the blast pressure. No settled ratio between these quantities can be noticed. For instance, the results of the forty-three furnaces give the following:

Iron	Tuyère section per ton coke	Pressure
Foundry iron	3.84-13.3 sq. cm. 5.8 -12.6 sq. cm. 3.6 - 9.32 sq. cm.	14.0-24 cm. 22.5-75 cm. 24.0-68 cm.

Some Constants for the Metallurgy of Iron HEAT CONTENT OF PURE IRON¹

Temp.	Total heat	Temp.	Total heat	Temp.	Total heat
250	30.5	750	125.6	1250	208.3
300	37.7	800	135.8	1300	216.1
350	45.0	850	144.4	1350	224.2
400	52.2	900	152.8	1400	233.1
450	60.3	950	160.4	1450	241.4
500	68.3	1000	167.8	1500	250.0
550	76.7	1050	175.4		1
600	85.0	1100	183.0		1
650	95.1	1150	191.7		
700	111.8	1200	200.0		

Snrinka	age or	Cas	stings per root	
Cast iron	. 1/8	in.	Zinc	5/16 in.
Brass	. 3/16	in.	Tin	1/2 in.
Steel	. 1/4	in.	Aluminum	3/a in.
Malleable iron	. 1/8	in.	Britannia	1/32 in.

¹ P. Overhoffer, Metallurgie, June 22, July 8 and 22, 1907.

As to American blast furnace practice, according to A. N. Diehl (Amer. Iron and Steel Inst., May 28, 1915) although we have a few instances where coke consumption is down between 1600 and 1700 lb. per ton of iron produced, nevertheless he believes the best 1915 practice is not far from the best Duquesne practice of 1897–1899, and gives the following to support this view:

AVERAGE PRACTICE AT DUQUESNE BLAST FURNACES FOR 1897 AND 1899

	1897		1899	
	Bessemer	Basic	Bessemer	Basic
Daily product, tons	477	438	509	565
Coke per ton iron, pounds	1.940	2,016		2.001
Silicon in iron, per cent	1.11	1.00		0.59
Sulphur in iron, per cent	0.023	0.034		0.048
Ratio coke to ore	2.027	1.934		2.105
Per cent. Mesabi ore used	37.48	36.88		39.83
Per cent. flue dust made	4.1	5.3		4.0
Flue dust per day, tons	35	39	45	42
Flue dust per month, tons	. 1,069	1,398	1,362	1,288
Theoretical slag volume	1,108	1,157	*	•
Silica in slag	33.03	32.96	33.75	33.11
Alumina in slag	14.01	14.37	15.00	14.34
Cu. ft. air per minute	40,352	37,244	53,765	54,423
Cu. ft. air per ton iron	118,096	121,044	146,566	134,352
Cu. ft. air per lb. coke	60.7	60.0	74.0	67.3
Silica in ores	5.8	6.2	•	•
Heat in blast	925	950		1,025
Percentage limestone	24.5	24.3	22.4	21.5

Three furnaces working bessemer; one furnace working basic.

COMPARISON OF FURNACE PRACTICE 1897-1899, 1912-1914

-	Daily	Daily Coke,		Ana	Heat
	output, tons	sump- tion, pounds	Silicon, per cent.	Sulphur, per cent.	
Bessemer, 1897–99	502 524 529.3	1,979 1,943 1,925	1.17 0.71	0.026 0.041	948 1,013 1,085

Charcoal Analysis.—According to J. E. Johnson, Jr., the average analysis of kiln birch and maple charcoal is as follows: CO₂, 4.50 per cent.; O₂, 0.67; H₂, 1.65; CO, 11.10; CH₄, 3.40; N₂, 7.77; fixed carbon, 68.50; ash, 1.00 per cent. Retort charcoal is commonly believed to be a little higher in fixed carbon. Owing to its thermal conductivity a 2-in. lining of zirconia is equal to 4 in. of chamotte. It is practically unaffected except by molten fluorides and bisilicates.

Screen Analysis of Ores.—In considering the advisability of briquetting or sintering any given ore, the point brought up by

^{*} Not calculated.

A. N. Diehl (Am. Iron & Steel Inst., May, 1915) should be considered. This is, that the ordinary screen analysis of dry ore is misleading, as fine particles cling to the larger ones. He therefore gives it as his opinion that wet sieving tests should be used, as in these the fine particles are washed through the screens and one obtains a better classification. He gives some comparative tests as follows:

COMPARISON OF DRY AND WET ANALYSIS OF ORES

	Ore No. 1, per cent.		Ore No. 2, per cent.		Ore No. 3, per cent.	
•	Dry	Wet	Dry	Wet	Dry	Wet
On 20-mesh screen	54.59	46.40		46.00		57.70
On 40-mesh screen On 60-mesh screen		13.80 3.30		8.40 3.60		10.20 2.90
On 80-mesh screen		5.80		4.40	1.25	3.30
On 100-mesh screen	4.67	1.10		0.70		0.80
Through 100-mesh screen	16.24	29 .60	13.44	36.90	11.95	25 .10
	100.00	100.00	100.00	100.00	100.00	100.00

THERMOCHEMISTRY OF THE IRON BLAST FURNACE

Reaction	Calories
$3\text{FeO} + \text{Si} = \text{FeSiO}_{\bullet} + 2\text{Fe}$	= +100,040
FeO + Mn = MnO + Fe	= + 26,200
$8FeO + 2P = Fe_3P_2O_3 + 5Fe$	= + 168,700
FeO + C = CO + Fe	= - 35,600
$SiO_2 + 3 CaO = CaSiO_2$	= + 15,200
$P_2O_5 + 3CaO = Ca_2P_2O_3$	= + 78,700
$FeSiO_2 + CaO = CaSiO_2 + FeO$	= + 5,600
$Fe_{1}P_{2}O_{3} + 3CaO = Ca_{1}P_{2}O^{2} + 3FeO$	= + 26,340
$MnSiO_3 + CaO = CaSiO_3 + MnO$	= + 10,200
$Mn_sP_2O_s + 3CaO = Ca_2P_2O_s + 3MnO$	= + 19,100
$FeSiO_2 + C = SiO_2 + Fe + CO$	= -45,600
$MnSiO_2 + C = SiO_2 + Mn + CO$	= -67,200
$Fe_2P_2O_3 + 3C = P_2O_3 + 3Fe + 3CO$	= -159,160
FeO + C = Fe + CO	= - 35,600
MnO + C = Mn + CO	= -61,800
$Fe_2P_2O_3 + 3SiO_2 = 3FeSiO_2 + P_2O_5$	= -22,360
$Ca_2P_2O_3 + 3SiO_2 = 3CaSiO_2 + P_2O_3$	= - 31,900
$P_2O_3 + 5C = 2P + 5CO$	= -260,500

Loss of Heat in Subterranean Gas Conduits.—The following table is given by M. Quasebart in Stahl und Eisen, 1913, p. 492.

Gas temperature,	Loss in deg. per meter of length,
°C.	°C.
700-600	3 . 5
600-500	3 . 0
500-400	2.5
400-300	2.0
300-200	$\overline{1.0}$

STEEL CONVERTING—HEAT EFFECT OF OXIDIZING 1 Kg. OF MATERIAL

	Heat of oxida- tion	Formation of	Total heat developed	Chilling effect of blast, ra- distion, etc.	Net heat avail- able for raising temperature	Theoretical rise in tem- perature
Silicon. Manganese Iron (to FeO). Iron (to Fe ₂ O ₂) Titanium. Aluminum. Niekel Chromium. Carbon (to CO ₂). Carbon (to CO). Phosphorus.	7,000 1,653 1,173 1,740 4,542 7,272 1,051 2,344 8,100 2,430 5,897	159 159	7,000 1,751 1,332 1,905 4,542 7,272 1,210 2,344 8,100 2,430 8,460	1,688 430 422 825 1,022 1,305 378 887 8,936 2,572 (2,477 (2,2531)	5,312 1,321 910 1,080 0,100 5,967 832 1,457 4,164 -142 3,739	Deg.C. 188 51 33 42 133 224 33 56 143 ~5

Basic-lined Open Hearth (Monell Process)1

Fifty tons pig iron at 1300°C. run in on 15 tons of ore (90 per cent. Fe₂O₂; 10 per cent. SiO₂) also heated to 1300°C. There is 2000 lb. CaO on the ore. The reaction requires about 20 minutes.

ANALYSIS OF METAL

	On running in	After reaction
Carbon	3.50	3.00
Silicon	2.00	0.00
Phosphorus	0.75	0.00
Manganese	0.50	0.00
Iron	93.25	97.00
-	Heat evolved	Cal.
8i to 8iO2	2,000×7,000 =	14,000,000
P to P.O.	$750 \times 5,892 =$	4,419,000
Mn to MnO	500×1,653 =	826,500
C to CO	$471 \times 2,430 =$	1,144,500
SiO ₂ to FeO·SiO ₂	$7,286 \times 144 =$	1,049,200
CaO to 3CaO P.O.	2,000× 949=	1,898,000
AND ALBORO TEASTITION	=100014 080	_,000,000
•		

¹ Chilling effect of lime added, preheated to 600°.

² J. W. RICHARDS, "Metallurgical Calculations," Vol. II.

PIG-IRON CONVERTING DATA

	C, per cent.	P, per cent	Si, per cent.	Mn, per cent	S, per cent.
Charge	2.98	0.10	0.94	0.43	0.06
After blowing 9 min. 10 sec	0.04	0.11	0.02	0.01	0.06

Slag formed: SiO₂, 63.56 per cent.; Al₂O₃, 3.01; FeO, 21.39; Fe₂O₃, 2.63; MnO, 8.88; CaO, 0.90; MgO, 0.36. Gases produced: CO₂, 5.20 per cent., CO, 19.91; H₂, 1.39;

N₂, 73.50 per cent.

Heat Balance Sheet (Blowing 22,500 Lb. of Above Pig)

Heat in converter body at starting Heat in melted pig iron Heat in spiegeleisen Heat in blast Heat of oxidation Heat of formation of slag	8,034,970 6,750,500 750,000 86,580 4,510,800 ¹ 59,890
Total on hand and developed	20,192,740
Heat in converter body at finish Heat in finished steel Heat in slag Heat in escaping gases Heat absorbed in decomposing moisture Heat conducted to the air Heat lost by radiation.	8,632,750 1,582,350 2,786,000 182,130 34,630
Total accounted for 1 Derived as follows:	20,426,870 1,139,670 cal.
C to CO ₂ C to CO. Si to SiO ₂ Mn to MnO. Fe to FeO. Fe to Fe ₂ O ₃	1,139,670 cal. 1,309,280 cal. 1,422,400 cal. 327,130 cal. 268,150 cal. 44,170 cal.
•	4,510,800 cal.

Tempering Ordinary Steel

Deg.	-	Color
200		Yellow
250		Brown
300		Light blue
350		Dark blue

	Heat absorbed	Cal.
Fe ₂ O ₃ to FeO. FeO to Fe. Fe ₃ C to Fe ₃ +C. FeSi to Fe+Si. Fe ₃ P to Fe ₃ +P.	$18,900 \times 573 =$ $4,681 \times 1,173 =$ $471 \times 705 =$ $2,000 \times 931 =$ $750 \times 1,400 =$	10,829,700 5,490,800 332,000 (?) 1,862,000 (?) 1,050,000 (?)
		19,564,500 (?)

BALANCE SHEET OF IRON BLAST FURNACE¹ (Per 1000 Units of Pig Iron)

Charges		Pig iron		Slag		Gases	
Ore	1530.2						·
Fe ₂ O ₂ FeO SiO ₂ MnO Al ₂ O ₂ CaO MgO P ₂ O ₄	1314.9 60.6 84.2 9.6 11.6 34.1 14.8 0.092 0.153		920.4 46.2 6.0 0.25	FeO SiO ₂ MnO Al ₂ O ₃ CaO MgO	11.6	0 0 0	0.05
Cu Limestone	0.11	Cu	0.11			O	0.01
Fe ₂ O ₃	0.2 3.6 0.4 62.2 0.2 0.007 0.001 49.1	P	0.003	FeO SiO2 Al2O2 CaO MgO	0.2 3.6 0.4 62.2 0.2	O	0.00
Charcoal	682.0	C	27.0			c	520 7
N	0.5 24.1 2.2 1.3 6.1 0.7 0.046 0.116 3.4 95.8		0.02		2.0 1.3 5.9 0.7 0.25 3.4	N O O	0.06
O ₂ N ₂						O N	557.7 1859.1
Totals	4744.8		1000.0		220.8	l	3543.7

¹ J. W. RICHARDS, "Metallurgical Calculations," Vol. II.

HEAT BALANCE, IRON BLAST FURNACE¹ (Per 100 Kg. of Iron)

Heat developed	Dry blast	Wet blast	
C to CO	92,950 Cal.	131,220	
C to CO ₂	206,955 Cal.	213,030	
Heat in blast	37,850 Cal.	39,385	
Solution of carbon in iron	2,820 Cal.	2,820	
Formation of slag	4,260 Cal.	4,425	
	344,835 Cal.	390,880	
Heat accounted for	Dry blast	Wet blast	
Reduction of iron	165,870	165,870	
Reduction of silicon	7.000	7,000	
Expulsion of CO_2	18,666	18,666	
Evaporation of moisture	11,342	11,342	
Heat in waste gases	23,799	43,836	
Decomp. of blast moisture	3,225	14,511	
Heat in slag	29,280	30,450	
Heat in pig iron	32,500	32,500	
Heat in cooling water	1 14.922	15,525	
Lost by radiation and conduction	37,791	51,180	
	344,835	390,880	
Carbon burnt at tuyères	58.05	75.3	
Total fixed carbon charged	67.8	84.3	
Proportion burnt of tuyères		89.3	
Fixed carbon really available		79.4	
Proportion burnt at tuyères		94.8	

CUPOLA CHARGES IN STOVE FOUNDRIES²

•	Foundry A	Foundry B	Foundry C	Foundry D ³	Foundry E
Bed of coke	1500	1600	1600	1800	1900
First iron charge	5000	1800	4000	5600	5000
All other iron charges	1000	1000	2000	2900	2000
First charge of coke	200	150	200	200	200
Second charge of coke	200	130	200	200	175
Four next charges	150	130	150	200	175
Six next charges	120	100	150	200	175
All other charges	100	100	150	200	175

J. W. RICHARDS, "Metallurgical Calculations," Vol. II.

** Kent's, "Mechanical Engineers' Pocket Book."

** A very high melting ratio for stove plate. About 8- to 14-os. blast is necessary for good melting. The metal loss will probably run from 4 to 6 per cent.

WASHING GASES WITH THIESSEN WASE	IER
----------------------------------	-----

	Hock	dahl		Hö	rde		
	Appa- ratus I, hot un- cleaned gas	Appa- ratus II	Schalke	Appa- ratus I, cool cleaned gas	ratus	Rom- bach	
Dust, grains per 1000 cu. ft.:							
Before washing	2.6 0.017		1.3-1.7 0.008		1.0 0.004	0.87 0.008	
Water, grains per 1000 cu. ft.:		,					
Before washing	7.8	10.4	15.0 % vol.	13.9	15.8	18.3	
After washing	3.1	2.2	12.20 % vol.	1.5	1.3	13.9	
Temperature of gas, deg. C.:	,			,			
Before washing	144.0	158.0	144.0	46.0	45.0	43.0	
After washing	30.0	37.0	30.0	33.0	28.0	36.0	
Temperature of water, deg. C.:							
Before washing	14.0	7.0	12.0	28.0	20.0	18.0	
After washing	39.0	40.0	55.0	37.0	34.0	19.0	
Cooling water consumed:							
Cubic feet per hour		424.0	360.0		247.0	360.0	
Gal. per 1000 cu. ft	8.22	7.48	7.48	7.78	7.93	8.45	
Volume of gas per hour,	807 180	492 400	280 080	529,500	211,800	317.700	
cubic feet	007,100	423,600	300,000	348,000	211,000	317,700	

¹ HOPMAN'S "General Metallurgy."

STEEL ROLLING

CUBIC MILLIMETERS OF STEEL DISPLACED BY 1 Kg.-m. OF ENERGY AT DIFFERENT TEMPERATURES 1

	At temperatures, deg. C.							
Square ingots to	1300	1200	1000	900				
FlatsRounds	100 80	45 50	20	18				
T-girders	85	67 70	20 20	10				

¹ HOFMAN's "General Metallurgy," p. 665.

Types of Electric Furnaces

Electric furnaces may be divided into three classes: (1) Arc: (2) resistance; (3) induction furnaces, according to the different

methods of applying the heat.

In the arc furnaces the heating is produced by radiation or conduction from an electric arc. This arc is formed by the passage of an electric current at 50 to 120 volts across the air gap between two carbon electrodes, or between one or more carbon electrodes and the surface of the molten metal, which then acts as the second pole of an electric circuit.

In resistance furnaces the heat effect is produced within the metal itself by the resistance offered to the passage of the current through it. The temperature attained by this method of heating cannot equal that attained in arc heating; the radiation and conduction losses are lower and the thermal efficiency of the

furnace is higher.

Induction furnaces form really a subdivision of the resistance type of furnace, since the thermal effect is again due to the resistance of the metal to the flow of current through it. In this case, however, induced currents of electricity are used in place of direct current. The induction furnace is in fact nothing but a great step-down transformer in which a ring of molten metal forms the secondary circuit and becomes the focus of current of large intensity but low e.m.f. The disadvantages of this type of furnace are its comparatively low temperature and the necessity for retaining a certain proportion at every melt in the annular ring in order to carry the current for melting the next charge. A great advantage is that electrodes are dispensed with and that this costly item of running charges is wiped out. A secondary advantage is that the capital expenditure upon cables and conductors is greatly reduced.

The chief commercial types of furnace fall into the classes as follows: (1) arc—Chaplet, Grönwall, Girod, Heroult, KELLER, NATHUSIUS, SNYDER, STASSANO; arc and resistance— HÄRDEN, NAU, SODERBERG, STOBIE; resistance—Rochling, Rodenhauser, Queneau (pinch effect), Hering (pinch effect); induction—Anderson, Colby, Frick, Hiorth, Kjellin.

Composition of the Silicides and Carbides² Ni₂Si, Co₂Si, Cr₂Si, Mn₂Si, Cu₂Si, Fe₂Si, FeSi, W₂Si₂.

1	2(a)	3(b)	4(c)	5(1)	6(d)	7(1)	8(1)	9(e)	10(1)
Li ₂ C ₂	CaC ₂ SrC ₂ BaC ₂	CeC ₂ LaC ₂ YtC ₂ ThC ₂	U2C3	wc	Al ₄ C ₃ Be ₄ C ₃	Cr ₂ C ₂	MoC W ₁ C	Mn ₂ C Fe ₂ C	Cr ₄ C

⁽a) All carbides of this group give acetylene when decomposed with water. (b) These carbides give off complex mixtures of acetylene, ethylene, methane and hydrogen, according to temperature employed. (c) This carbide when decomposed with water gives gases rich in methane. Only about one-third of the carbon is given off in this way, the remainder forms liquid and solid hydrocarbons and carbohydrates. (d) These carbides and water give methane only. (e) Manganese carbide and water give equal mixtures of methane and hydrogen. Iron carbide is not decomposed. (f) These carbides are not decomposed by water.

Electric Steel Furnaces¹
Power Consumption in Kilowatt-hours per Metric Ton of Steel Produced

	Cold charges composed of				Molten charges from			
	Scrap	Pig iron and Wal- loon iron	Average	Bessemer	Wellman open hearth	Martin open hearth	Cupola	Average for molten
Heroult	459 528		49 3	104 33	200	• • • •	• • • • •	146
Girod	750 850	• • • • • •		•••	200 200 275	••••	••••	237
Stassano	918 958	• • • • • •	800		••••		•••••	201
•	1000 1250			••••	••••	•••••	•••••	• • • • •
Röchling-	1260 640		1071	125				• • • • •
Rodenhauser				150 200	280		280	• • • • •
Frick	900 780		773	250	•••••		••••	214
Keller	800		790	••••	• • • •	275		275
Hiorth		680 720		•• • • •	••••		•••••	
Colby	605	790	730	•••••	••••	•••••	•••••	
Kjellin	825 650		715	••••	•••••	•••••	•••••	
	790 800		747	••••	••••		•••••	• • • • •

Power Consumption in Ferro-chrome Making²

The power consumption in a ferro-chrome furnace of the Meraker Electric Smelting Co., at Kopperaaen, Norway, was recently given as 3 kw.-hours per pound, or 0.68 kw.-year per short ton in making a ferro-chrome containing 5 per cent. carbon. At Kanawha Falls, W. Va., ferro-chrome was made in a crucible electric-arc furnace with a power expenditure of 3.6 kw.-hours per pound, or 0.72 kw.-year per ton. This product contained 70.96 per cent. chromium, 23.23 per cent. iron, 5.21 per cent. carbon, 0.5 per cent. silicon, 0.008 per cent. phosphorus, and 0.078 per cent. sulphur. At both Kopperaaen and Kanawha Falls an ore containing about 50 per cent. Cr₂O₄ was

¹ John B. Kershaw, "Electrothermal Methods of Iron and Steel Production."

² Iron Trade Review, May 13, 1915.

used. The Kopperaaen ferro-chrome contains 65 to 70 per cent. chromium. In the experiments of the writer, a product containing 50 to 68 per cent. chromium and 4.32 to 9.31 per cent. carbon was obtained with an ore containing 46.35 per cent. Cr₂O₂, and power consumption of 3.02 kw.-hours per pound or 0.69 kw.-year per ton. A 750-kw. furnace of the Alby Carbide type at Kopperaaen, operating continuously, uses on the average about 3 kw.-hours per pound of ferro-chrome produced, or 0.68 kw.-year per short ton, when chromite ore containing 50 per cent. Cr2O2 is charged; and the product contains 5 per cent, or more of carbon and 65 per cent. of chromium.

Electric Smelting of Iron Ores in Scandinavia

Owing largely to the availability of cheap hydroelectric power. electric smelting has progressed further in Scandinavia than elsewhere. Dr. Alfred Stansfield investigated the status of this industry in 1914 and his report, the "Electrothermic Smelting of Iron Ores in Sweden," issued by the Canadian Government, is a classic on this subject.

The report deals first with the "Elektrometall" furnace.

The Elektrometall Furnace

The "Electrometall" furnace in its most recent form has a circular crucible provided with one tapping hole, from which both the slag and metal are withdrawn, the metal and the slag being separated by a dam as they flow out, the former being cast into pigs or taken in a ladle to the Bessemen converter or open-hearth furnace. The crucible is lined with fire-brick like an ordinary blast furnace, and not as in the earlier forms of this furnace with magnesite. The chimney or stack of the furnace is constructed in a steel shell, and it is supported on steel beams independently of the crucible. The shaft is reduced to a neck, where it enters the crucible, so as to leave a free space for the introduction of the electrodes, and the tendency is, it is explained, to increase the width of this neck, particularly when powdery ores are being treated so as to leave a freer course for the passage of the gases up the shaft. The arch of the crucible. which is constructed of fire-clay bricks—not of magnesite or silica bricks—is cooled below by the introduction of cooled gases from the top of the furnace. It is also cooled on its upper surface by cold air from a number of pipes. The electrodes are circular and about 600 mm. (nearly 2 ft.) in diameter, and from 4 ft. to 5 ft. long. They can be attached end to end by moulded carbon nipples, which are screwed into threaded holes in their ends. The electrode holders consist of two inclined guides, between which the electrodes lie, supported by guide rollers. At the bottom of these guides is a water-cooled collar built into the furnace arch. The collar is supported from above, so that it does not press on the arch, and is packed around the electrode with asbestos in order to prevent the gases escaping from the furnace. Above the collar comes a water-cooled

contact ring, which consists of a number of metal blocks forming a flexible collar which can be tightened round the electrode. Each of these blocks is connected to one of the copper bus-bars by means of flexible cable. Above the contact ring, which is close above the furnace arch, is a clamping ring for feeding the electrodes. This ring grips the electrode and can be made to move up or down the guides by a pair of long screws. The two screws are operated from above by a ratchet, and they are connected together by gearing so that they must turn at the same time. As a rule, the electrodes do not require to be moved more often than once in 2 or 3 days.

Electrodes and the Supply of Current

The larger furnaces have six electrodes, which are supplied with three-phase current from three transformers. Each transformer is connected to two diametrically opposite electrodes, so that the electric current tends to pass between them instead of between adjacent electrodes, as in the earlier forms of this furnace. The voltage of each transformer can be regulated by means of tappings on the primary windings, and a nearly constant power can in this way be supplied to each pair of electrodes in spite of changes in the electrical resistance between them. It will be realized, therefore, that the regulation of the power is brought about by alterations to the voltage and not by moving the electrodes up and down.

Circulation of the Furnace Gases

A distinctive feature of the furnace is the circulation of the furnace gases. The gas, which is abstracted from the top of the furnace, is first of all passed through dust catchers, then through pipes where it meets a spray of water, then through a centrifugal fan or blower where it again meets a spray of water, and finally through a separating chamber where the entrained water is removed. The washed gas is supplied to six tuyères entering beneath the furnace arch and between two adjacent electrodes. The tuyères cannot be utilized for peep holes, since the dirt in the gas would quickly obscure any glass windows.

The operation of the furnace depends very largely on the circulation of the gases. By increasing the circulation the temperature of the shaft is increased, the reduction of the ore facilitated, the percentage of CO₂ in the escaping gases raised, and the economy, both in electric power and in fuel, improved. The electrodes are, however, more quickly consumed as they are attacked by the escaping gases. At present, apparently, the heat in the escaping gases is not yet fully utilized in Sweden, but the author remarks that it probably will be employed in heating open-hearth furnaces and for similar purposes, which will represent an important economy in the operation of the furnace.

The Helfenstein Furnace

The Helpenstein furnace has a large smelting chamber, which is usually rectangular in plan. The electrodes, which enter the chamber through the roof, are arranged vertically. The ore charge is fed in through a number of chutes, and it is not heated beforehand. Indeed, the large shaft or chimney, which forms such a feature of the Elektrometall furnace, being as it is much larger than the crucible, is entirely omitted, and the gases escape through the charging chutes. The omission, however, renders it possible to construct a smelting chamber in which a large amount of energy can be utilized. Dr. Stansfield points out that the economy of electric furnaces increases with the amount of power employed in them. Hence by building a Helfenstein furnace to consume, say, 12,000 h.p., as compared with the 4000 h.p. used in the Elektrometall furnace. the increased efficiency may counterbalance the loss of economy resulting from the fact that the charge is not preheated. again, the gases given off by the Helfenstein type of furnace are greater in volume and richer in carbon monoxide than the gases evolved from the Elektrometall furnace, and will have a greater value for heating open-hearth or other furnaces.

The Tinfos Furnace

A third furnace, known as the Tinros, consists of a long rectangular heating chamber with two chutes leading down into it. The roof between these chutes is carried by two water-cooled beams, which run the whole length of the furnace and which are arranged just sufficiently far apart to permit of the insertion of three rectangular electrodes. All these three electrodes are connected to one pole of the supply current. The corresponding electrode lies at the bottom of the furnace, and is covered with a bed of rammed coke, which forms the working bottom and has been found so Mr. Stansfield says, to last very well. Three of these furnaces, each consuming 1600 h.p. in single-phase current, are in operation in Norway.

Comparison of the Three Furnaces

In discussing these three types of furnace, Mr. Stansfield remarks that since the Tinfos furnaces consume such a comparatively small amount of power and work under such different conditions to the others no useful comparison can be drawn between its and their efficiencies. But in comparing the Elektrometall and Helfenstein types he points out that whereas in the former difficulty is experienced when using very powdery ores owing to the charge in the shaft becoming too compact for the passage of the gases, this difficulty is far less serious in furnaces of the Helfenstein type. Then, again, the Elektrometall furnaces all use charcoal as the reducing agent. Attempts to use coke have not been very successful. Less difficulty is experienced in burning coke in the Helfenstein furnace, and coke is regularly used in the Tinfos furnaces.

All the ores smelted in Sweden are high in iron. A typical ore is 60 per cent. Fe, 5 per cent. SiO₂, 1 per cent. P and traces of sulphur. Charcoal and fluxes are used and phosphoric pig iron is produced running about as follows: Si, 0.5–1.0 per cent.; Mn, 1 per cent.; P, 2 per cent.; S, 0.01 per cent.; C, 3.6–3.8 per cent. The manganese was provided by means of Bessemer slag and phosphorus is supplied by apatite. The iron is converted into steel by the basic Bessemer process.

At Domnarfvet each Elektrometall furnace requires per ton of Bessemer iron from 60 per cent. ore 2245 kw. of electric energy, 23.6 hectoliters of charcoal, 52 kg. of Bessemer slag, 30 kg. of apatite and about 7 kg. of electrode. According to Dr. Stansfield the cost of energy is about 0.16 cts. per kw.-hr.

At Hagfors, where the whole charge (including flux) averages 52 per cent. Fe, 2500 kw. of electric energy, 21 hectoliters of charcoal, 180 kg. of limestone and 6 kg. of electrodes are required to produce 1 ton of acid open-hearth steel.

A three-furnace plant—Elektrometall—cost about \$300,000 before the war, the furnaces being 3000-4000 h.p. capacity.

The output per furnace was from 20 to 30 tons.

624 METALLURGISTS AND CHEMISTS' HANDBOCK

ELECTRIC CONDUCTANCE OF ORE-FORMING MATERIALS¹

Metal	Good conductor	Inferior or non-conductor
Silver	Argentite, pyrargyrite,	
Copper	proustite. Chalcocite, chalcopyrite, bornite.	Cuprite, azurite, mala- chite, tetrahedrite, chrysocolla.
Lead Cobalt	Galena. Smaltite, linnæite, cobaltite.	Cerussite, pyromorphite, crocoite, wulfenite, anglesite, bournonite.
Nickel	Gersdorffite, niccolite, rammelsbergite.	
Tin	Cassiterite.	Stannite.
Zinc Antimony		Blende, calamine, smithsonite, stibnite.
	Pyrite, pyrrhotite, mag- netite.	

¹ HOFMAN, "General Metallurgy."

SECTION XI

ORGANIC CHEMISTRY

The object of this section is to serve only as a reminder of simplest formulas and properties of the more common organic compounds. Carbon differs from the other elements, except perhaps silicon, in its ability to form highly complex molecules, carbon being linked to carbon, and also in the readiness with which several of its valences will be satisfied by another carbon atom. Thus, the structural formula of methane, marsh gas, is

The benzene ring is H-C C-H, and the double ben-

$$\mathbf{H} \subset \mathbf{C}$$

zene ring, or naphthalene is H-C

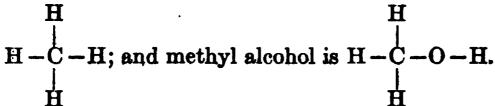
H

A series, such as the marsh gas series, is methane, H - C - H;

of such compounds is said to be homologous, and the compounds are homologues. As will be seen, each of the above compounds corresponds to the formula CnH_{2n+2} (paraffin series); the olefines correspond to CnH_{2n} ; the acetylene series to CnH_{2n-2} ; the benzene series to CnH_{2n-6} , etc.

Alcohols

In general the first step in the oxidation of a hydrocarbon is the formation of a hydroxyl group replacing a hydrogen. These products are the alcohols and are bases. Thus methane is



Alcohols may be polybasic. Thus the common compound glycerin in the simplest tri-basic alcohol and is formed by the introduction of a hydroxyl into each group of a propane mole-

In regard to this same compound, propane, it will be noticed that while the compounds CH₂·CHOH·CH₂ and CH₂·CH₂·CH₂·OH are both alcohols of the same number of carbon, hydrogen, and oxygen atoms, their structural formulas are unlike, and their properties differ in some degree. Such compounds are known as metameric. When the percentage composition is the same they are isomeric, the latter including the former class. In general it may be said that after leaving the simpler compounds, a mere knowledge of the number of atoms of carbon, hydrogen, oxygen, etc., in an organic compound is no guide whatever to its properties.

Aldehydes

If the attempt be made to substitute a second hydroxyl in the same carbon group in an alcohol, water will be split off.

Thus, with methyl alcohol the product is not $\begin{array}{c} H & O-H \\ \hline H & O-H \end{array}$

will be an aldehyde with the characteristics of these compounds, pleasant odor, great reducing power, etc.

Acids

By further oxidation of an aldehyde R — CHO and the conversion of the last hydrogen into a hydroxyl an acid is produced. Thus, H — CO·OH is formic acid; CH₂CO·OH is acetic acid. Acids may contain two acid groups. Thus, if both carbon groups in ethane be oxidized to —COOH we have oxalic acid HO·OC — CO·OH.

Acetones or Ketones

In general hydrocarbon groups connected by a =CO group are known as "ketones." The simplest of these are acetone, H₂C

C=0, and formaldehyde C=0.

H₃C

H

Ethers

Just as alcohols are hydroxides of the hydrocarbons, ethers CH.

are oxides. Thus, methyl ether is O

; ethyl ether (the

CH₂·CH₃

sulphuric ether of commerce) is O

There is no sul-

CH₂·CH₃

phuric group in this, the name comes from the fact that sulphuric acid is used in its manufacture. It will be seen that the formula of methyl ether (an oxide) is C₂H₆O, while the formula of ethyl alcohol (a hydroxide) is also C₂H₆O, lending point to the remarks above concerning empirical formulæ and their limitations.

Halogen Substitution Products

The hydrogen atoms of the hydrocarbons may readily be directly replaced by the halogens. Thus $H - C \equiv Cl_{\bullet}$ is the well-known compound chloroform. Again pointing out that even in the simplest compounds different structures may be

present, I-C-C-I is not the same as I-C-C-H.

H H
H H

Substituted Ammonias

The well-known "amines" are ammonias in which one or more hydrogen atoms have been substituted by hydrocarbon groups. Thus, ammonia is NH₂; methyl-amine is CH₂·NH₂; dimethyl-amine is NH(CH₂)₂; ethyl-amine is CH₂·CH₂·NH₂. The compound H₂N - NH₂ is known as hydrazine. These are all powerful bases. A short table of the principal physical properties of the common organic compounds is appended.

A TABLE OF COMMON

	•		Solubility	
	Formula	Structure	Water, 20°C.	Water, 100°C.
Hydrocarbons Methane	CH ₄	All hydrogens symmetri-	0.003:100	i
Ethane	C ₂ H ₆	H ₃ C-CH ₃	0.006:100	i
PropaneButane	C ₈ H ₈ C ₄ H ₁₀	H ₂ C-CH ₂ -CH ₂ H ₃ C-CH ₂ -CH ₃	2:100vols.	i
Pentane	C5H12	H ₂ C-CH ₂ ·CH ₂ ·CH ₂ ·CH ₃ ·		
Hexane	CeH14	CH ₁ -CH ₂ -CH ₂ -CH ₂ -		
Ethylene	C2H4	$CH_2 = CH_2$	0.015:100	i
PropyleneButyleneAmylene	C ₄ H ₈	CH ₂ -CH = CH ₂ CH ₂ -CH = CH - CH ₃ CH ₂ = CH - CH ₂ -CH ₃ - - CH ₃	0.04:100	
Acetylene	C ₂ H ₂	сн=сн	0.12:100	i
Allylene Ethylacetylene		$CH_1-C = CH$ $CH_1-CH_2-C = CH$	•••••	• • • • • • •
Bensene	C7H8	The bensene ring. CH ₂ -C ₆ H ₅ CH ₂ -C ₆ H ₄ -CH ₂	0.07:100	
Naphthalene Anthracene Terpene	C14H10	The double benzene ring. The triple benzene ring. Several compounds exist.	••••••	• • • • • • •
Amines Methyl-amine Dimethyl-amine Ethyl-amine Hydrazine Alcohols Methyl alcohol	C2H7N C2H7N N2H4	H ₂ =N·CH ₃ H-N=(CH ₃) ₂ H ₂ =N-CH ₂ -CH ₃ H ₂ =N-N=H ₂ CH ₃ -OH	00	
Ethyl alcohol	C_2H_6O	CH ₂ ·CH ₂ ·OH	∞	œ
Propyl alcohol Butyl alcohol Amyl alcohol	$C_4H_{10}O$	CHrCHrCHrOH CHrCHrCHrCHrOH CHr(CHr)rCHrOH	22.5:100 6:100	20:100 2:100
Allyl alcohol	C ₂ H ₅ O	CH ₂ = CH - CH ₂ OH		• • • • • •
Glycerin	CaHaOa	Сн•он-снон-сн•он		
Pyrogallol	C ₆ H ₆ O ₄	CeHa(OH):	62:100	V.8.
Phenol	C ₆ H ₆ O	C ₆ H ₅ OH	8.3:100	33 at 68°
Aldehydes Formic aldehyde Acetic aldehyde	CH ₂ O C ₂ H ₄ O	H ₃ =C=O CH ₃ -CHO	y.s.	V.S.
Paraldehyde	(C.H.O);	· 	12.5:100	6.6:100

ORGANIC COMPOUNDS

		T		
Alcohol	Melting point, °C.	Boiling point, °C.	Specific gravity	
<u> </u>	· · · · · · · · · · · · · · · · · · ·	1		
	-186	-152	0.415 at -164°	Commonly known as marsh gas or fire damp.
	• • • • • • •	-90		Easily formed by electrolysing acetic acid.
• • • • • • •	• • • • • • • •	$\begin{array}{c c} -27 \\ 1 \end{array}$	0.600 at 0°	The properties are those of the normal
•••••	• • • • • • •	37	0.636 at 17°	butane. There are three pentanes theoretically
• • • • • •	• • • • • • •	69	0.675 at 17°	possible. Five hexanes are theoretically possible.
• • • • • • •	<-110	- 105		Prepared by heating ethyl alcohol and H ₂ SO ₄ to 175°C.
		-48.5 -5	0.739 at 0°	11304 60 175 C.
• • • • • • •	• • • • • • • •	40	0.652 at 17°	•
	• • • • • • •	-84		Commercially prepared from calcium carbide.
			• • • • • • • • • •	
	5.4		0.88 at 15°	
• • • • • • • •	-54	112 140	0.87 at 18° 0.86 at 18°	The constants are those of the ortho-
9.8:100	80	218	1.15 at 20°	xylene.
0.08:100	213	251 165		The properties are those of terpene derived from amber.
	Gas	Gas		A stronger base than ammonia.
	• • • • • • • •	7.2	0.697	- See See See See See See See See See Se
	• • • • • • •		0.696 at 8°	
co	• • • • • • •	66.7	0.796 at 20°	Wood alcohol. Usually prepared by
c	-112	78.4	0.800 at 20°	destructive distillation of wood. Grain alcohol. Usually prepared by
	· · · · · <u>· · ·</u> ·	97.3	0.805 at 20°	fermentation of grain. Found in small amount in fusel oil.
	-22	117 137	0.817at20°	There are three butyl alcohols possible. Found in fusel oil. Eight alcohols are
• • • • • • •	••••••	96.6	0.85 at 20°	possible. Formed by heating glycerin with oxalic acid.
	17	290	1.26 at 20°	The simple tri-basic alcohol. Found
100: 100	132	294	1.45 at 20°	as an ester in tallow, palm oil, etc. Prepared by the dry distillation of gallic acid.
• • • • • • •	4 3	183	1.06 at 20°	Usually known as carbolic acid, but really an alcohol.
	• • • • • •	-21 20.8	0.81 at -21°	Formalin, formaldehyde.
				A powerful reducing agent. Poly- merises readily to paraldehyde. A powerful reducing agent. Forms
				spontaneously from acetaldehyde.

A TABLE OF COMMON

		AIA	BLE OF (JOHEON
	_	-	Solubility	
	Formula	Structure	Water, 20°C.	Water, 100°C.
Acids Formic acid	CH ₂ O ₂	н-соон	ω	ω
Acetic acid	C2H4O2	Сн. СООН	œ	&
Propionic acid Butyric acid Valeric acid	C ₄ H ₈ O ₂	C ₂ H ₅ ·COOH C ₃ H ₇ ·COOH C ₄ H ₉ ·COOH	22,6	36.3
Caproic acid	C ₆ H ₁₂ O ₂	C ₆ H ₁₁ ·COOH		
Caprylic acid Capric acid Palmitic acid Stearic acid Bensoic acid Picric acid Oxalic acid Oxalic acid	C10H20O2 C16H32O2 C18H36O2 C7H6O2 C6H2O7N3 (COOH)2			5.88:100 6.75:100 70:100 100:100
Lactic acid	i	CH3-CHCOOH	V.8.	v.s.
Succinic acid		(CH ₂ -COOH) - (CH ₂ COOH)		
Malic acid		(CHOH – COOH) – (CH ₂ COOH) CH ₂ OH·COOH	V.S.	V.8.
Citric acid		$(CH_2-COOH)_2-$	190 - 100	0.85:100 250:100
Tartaric acid		$ \begin{array}{c} C \subset OH \\ COOH - COOH \\ CHOH - COOH \end{array} $	v.s.	V.8.
Oleic acid	•	H C ₆ H ₁₇ C = C (CH ₂) ₇ -		•••••
Fulminic acidGallic acid	CNOH C7H6O5	$COOH$ $C = N - O - H$ $C_6H_2(OH)_2 - COOH + H_2O$		33:100
Halogen Compounds Di-iodo-methane	CH ₂ I ₂	Substitution product	1.1.100	33.100
Chloroform	CHCl.	Substitution product.	0.71:100	V.8.
Bromoform	CHI:	Substitution product. Substitution product.	0.01:100	v.s.
Chloral	C ₂ HOCl ₂	CCL ₈ ·CHO	See note	
Carbon tetrachloride Miscellaneous		Substitution product		
Methyl ether Sulphuric ether	C ₂ H ₆ O C ₄ H ₁₀ O	$CH_3-CH_2-O-CH_2-$		
Acetone	CaH6O CaH6O2	CH ₂ ·CO·CH ₂ CH ₂ = CH·CH ₂ ·OOC·- CH ₂	6.95:100	l.s.
Amyl acetate. Cane sugar Glucose. Starch Anilin Cellulose.	C12H22O11 C6H12O6 (C6H10O5)n C6H7N	CH ₂ ·CH ₂ ·COOH CH ₂ ·OH(CHOH) ₄ ·CHO Very complex molecule. C ₆ H ₅ ·NH ₂ Very complex molecule.	0.2:100 v.s. v.s. i 3.4:100	v.s. i 6.0:100 i

ORGANIC COMPOUNDS

		,	~	
	1	ł		1 .
	Melting	Boiling	Specific	
A1 1 1	point,	point,	gravity	İ
Alcohol	°C.	°C	G -4.1-15	
ı				
		<u> </u>	<u>'</u>	
•••••	8.6	100.6	1.22 at 0°	So called as it may be distilled from ants. A strong acid.
	16.5	113	1.06 at 0°	Produced by the oxidation of alcohol, or the distillation of wood.
	-23	140.9	.996 at 0°	
•••••	0	162.5	.961 at 0° .942 at 0°	Found in butter as the glycerol ester.
•••••	-18	186	.942 at U	Found in valerian root. There are four of these alcohols possible.
•••••	-1.5	205	.929 at 0°	All these acids have the normal struc- ture.
••••	16.5	236	.911 at 0°	vare.
••••	31	270	1	
••••	69.2	>270 >290	1.00 at 0°	Found as the glycerol ester in palm oil. Found as the glycerol ester in tallow.
54:100	121.4	249	1.00 200	Can be sublimed from gum benzoin.
	1			
26:100	101.5		2.00 at 9°	The strongest organic acid.
39:100			1.63 at 9°	
	Decomn	Decomp	1.24 at 15°	Produced by fermentation of mills.
•••••	133	150	1.53 at 9°	Found in amber.
•••••	133	Decomp.	1	round in amber.
*****	 .	120	1.56 at 4°	Found in apples, cherries, etc.
•••	80	Decomp.		Found in green grapes and in beets.
F0 100		175		
52:100	153	Decomp.	1.00	Found in lemons.
	168		1.76 at 7°	Found in grapes.
1.				Tannin. Formed artificially by dehy-
				dration of gallic acid.
•••••	14		.81 at 19°	Found as its glyceride olein in olive oil, lard, etc.
				Fulminate of mercury (CNO)2Hg.
24:100	Decomp.			
	220			
	2	180	3.32 at 19°	A liquid of high sp. gr. Hence used
	-70	61.2	1.49 at 20°	in laboratory separation of minerals.
: • • • • • • • • • • • • • • • • • • •	7.6		. 2.9 at 15°.	
1.4:100	119	• • • • • • • •	2.0-3.0	A powerful germicide of unpleasant odor.
.20:100		98	1.54 at 0°	Unites with one molecule of water
		,		forming chloral hydrate, which melts
	·	78.7	1.59 at 20°	at 57°, boils at 97.5°.
•••••		10.1	1.00 & 20	
		-25	.713 at 18°	
		34.9 56.5	.713 at 18°	·
•••••			.928 at 18	
			_	
			0.88 at 18°	Saccharose.
				Grape sugar, starch, starch sugar.
i			1.52	Amylum.
••••	-8	184	1.02 at 20°	The base of most coal-tar drugs and
_	ı l	Į į	l	dyes. A weak base.

SECTION XII

FIRST AID

INSTRUCTIONS FOR FIRST-AID TREATMENT¹

Wounds that Bleed—Abrasions, Cuts, Punctures.—Drop 3 per cent. alcoholic iodine into wound freely; then apply dry sterile gauze to wound and bandage it. Do not otherwise cleanse wound.

Severe Bleeding.—Place patient at rest and elevate injured part. Apply sterile gauze pad large enough to allow pressure

upon, above and below wound. Bandage tightly.

If severe bleeding continues apply tourniquet between wound and heart and secure doctor's services at once. Use tourniquet with caution and only after other means have failed to stop

bleeding.

Nose Bleeding.—Maintain patient in upright position with arms elevated. Have him breathe gently through mouth and not blow nose. If bleeding continues freely, press finger firmly on patient's upper lip close to nose or have him snuff diluted

white wine vinegar into nose.

Injuries which do not Bleed—Bruises and Sprains.—Cover injury with several layers of sterile gauze or cotton, then bandage tightly. Application of heat or cold may help, other means are unnecessary. If injury is severe place patient at rest and elevate injured part until doctor's services are secured.

Bromine Burns.—Wash with one volume 25 per cent. ammonia, one volume turpentine, ten volumes 96 per cent. alcohol.

Bromine or Chlorine Fumes.—Inhale the vapor from a mixture of turpentine and ethyl alcohol and summon a physician.

Eye Injuries.—For ordinary eye irritations flood eye with 4 per cent. boric acid solution. Remove only loose particles which can be brushed off gently with absorbent cotton wrapped around end of toothpick or match.

Do not remove foreign bodies stuck in the eye. In that case and for other eye injuries, drop castor oil freely into eye, apply

sterile gauze, bandage loosely and go to doctor.

For oils in the eyes wash with 5 per cent. ethyl alcohol; for alkalis, with 3 per cent. boric acid or 1 per cent. acetic acid; for acids, with 3 per cent. sodium bicarbonate solution. These solutions should be kept on hand.

¹ From a Bulletin of the Conference Board on Safety and Sanitation (National Affiliated Safety Organizations; M. W. ALEXANDER, Secretary, West Lynn, Mass.). Copyright, 1914. Reprinted from Engineering News.

For electric flash keep the victim's eyes closed and apply a compress of boracic acid solution (1 teaspoonful to a cup of water). Keep eyes closed and the compress on until a physician arrives.

Fire, Electrical and Sun Burns.—Do not open blisters. Use burn ointment (3 per cent. bicarbonate of soda in petrolatum) freely on sterile gauze applied directly to burn. Cover with several thicknesses of flannel or soft material, then bandage but not tightly. A 0.5 per cent. solution of picric acid is very good and if neither this nor the soda is available, a paste of flour in water. Lacking this, use a heavy oil, such a machine or transformer oil. On a dry charred burn use only a dry dressing.

Acid Burns.—Thoroughly flush wound with water, then dry wound, apply burn ointment and bandage as above. An alternative treatment is to wash with a mixture of seven parts glycerol, one part water and two parts ammonia and then to smear with a salve of ten parts vaseline, one and one-half parts

paraffin oil and two parts magnesia.

Alkali Burns.—Thoroughly flush wound with water, then flood with white wine vinegar to neutralize (dilute vinegar for alkaline eye burns), dry wound, apply burn ointment and bandage as above. Another mixture for washing alkali burns is six parts glycerol, three parts water and one part 80 per cent. acetic acid.

Asphyxiation or Electric Shock.—See page 588.

Chills and Cramps.—Give patient 20 to 30 drops of Jamaica ginger in hot or cold water. If no improvement, send for doctor.

Cinders in the Eye.—Roll soft paper up like a lamp lighter and wet the tip to remove, or use a medicine dropper to draw it out. Beware of infecting the eye with a dirty handkerchief corner or similar material. Rub the other eye.

Dislocations.—In case of dislocation of finger except second

Dislocations.—In case of dislocation of finger except second joint of thumb, grasp finger firmly and pull it gently to replace joint, then place finger in splint and bandage. In other cases

rest dislocated part and secure doctor.

Fainting.—Place flat on back; allow fresh air, and sprinkle

with water.

Fractures.—Make patient comfortable and secure doctor's services at once. Avoid unnecessary handling to prevent sharp edges of broken bones tearing artery. If patient must be moved, place broken limb in as comfortable position as possible and secure it by splint.

Frost Bites.—Rub with ice, snow or cold water, then treat

as "fire burns."

Heat Prostration.—Give patient teaspoonful of aromatic spirit of ammonia in hot or cold water. In case body feels warm apply cold to it; if necessary give cold bath. In case body feels cold and clammy, apply heat to it and send for doctor.

Internal 'Poisoning.—Immediately secure doctor's services. Make patient drink large quantities of water, preferably warm,

and make him vomit by sticking one's finger down his throat or by other means. See "Antidotes," below.

Lightning.—Dash cold water over a person struck. See also

p. 587.

Mad Dog Bite.—If a person is bitten by a dog that has rabies the only reasonable course is to be treated at a Pasteur Institute as soon thereafter as possible. Sucking the wound or cauterization will give a physically clean wound, but is of no avail against the virus of rabies.

Scalds.—Cover with cooking soda and lay wet cloths over it. Whites of eggs and olive oil. Olive or linseed oil, plain, or mixed with chalk and whiting. See also "Burns," p. 584.

Snake Bite.—Tie cord tight above wound. Open the wound with a knife and suck out the blood at once. A dressing of potassium permangate may be applied to the wound. Alcohol is useless. Usually a doctor must first treat a case of alcoholism when called in to treat a snake bite.

Shock, Following Injury.—In case shock is due to severe bleeding, control it first as directed under "severe bleeding"

and summon a doctor.

Lay patient flat on back and keep him warm with blankets, hot-water bottles, etc., and provide plenty of fresh air. Let patient inhale fumes of aromatic spirit of ammonia. If fully conscious give patient hot drink or teaspoonful of aromatic ammonia in hot or cold water.

Sunstroke.—Loosen clothing. Get patient into shade, and

apply ice-cold water to head.

Venomous Insect Stings, Etc.—Apply weak ammonia, oil, salt water, or iodine.

ANTIDOTES FOR POISONS

First.—Send for a physician.

Second.—Induce vomiting by tickling throat with feather or finger, drinking hot water or strong mustard and water. Swallow sweet oil or whites of eggs.

Acids are antidotes for alkalies, and vice versa.

Special Poisons and Antidotes

Acids.—Muriatic, oxalic, acetic, sulphuric (oil of vitriol), nitric (aqua fortis).

Soap-suds, magnesia, lime-water.

Prussic Acid.

Ammonia in water. Dash water in face.

CarbolicAcid.

Flour and water, mucilaginous drinks. Not a true acid, so alkalis are useless.

Alkalies.—Potash, lye, hartshorn, ammonia.

Vinegar or lemon juice in water.

Arsenic:—Rat poison, Paris green. Milk, raw eggs, sweet oil, limewater, flour and water.

Bug Poison.—Lead, saltpeter, corrosive sublimate, sugar of lead, blue vitriol.

ether.

Carbonate Soda.of Copperas, cobalt.

Iodine.—Antimony, tartar emetic.

Mercury and its salts.

Opium.—Morphine, laudanum, paregoric, soothing powders or syrups.

Whites of eggs, or milk in large doses.

Chloroform.—Chloral | Dash cold water on head and chest. Artificial respiration.

Soap-suds and mucilaginous drinks.

Starch and water, astringent infusions. Strong tea.

Whites of eggs, milk, mucilages.

Strong coffee, hot bath. Keep awake and moving at any cost.

CYANIDE POISONING

It is recommended that boxes labeled "Antidotes for Cyanide," with directions for use affixed to the lids of the boxes, should be kept in prominent and easily accessible parts of the cyanide plants. Each box should contain: a spoon and a metal receptacle to hold about 1 pt.; one blue hermetically sealed vial containing 30 cc. of 33 per cent. solution of ferrous sulphate; a white vial containing 30 cc. of 5 per cent. causticpotash solution; and one package, 30 grains, of oxide of magnesium (light). The directions for the use of the antidote should be as follows:

Preparation of Antidote.—Quickly empty the contents of the blue vial, of the white vial, and of the magnesia package into the metal receptacle, and stir well with the spoon. This should be done as rapidly as possible, as the patient's chance of life depends on promptness.

Administration of the Antidote.—If the patient is conscious, make him swallow the mixture at once and lie down for a few minutes. If the patient is not conscious, place him on his back and pour the mixture down his throat in small quantities, if necessary pinching his nose in order to make him swallow.

Incite Vomiting.—After the antidote has been given, try to make the patient vomit by tickling the back of the throat with a feather or with the fingers, or giving a tumblerful of warm water and mustard.

Then call the undertaker.

For cyanide eczema use equal parts by weight of calomel and bismuth subnitrate and apply locally. It will give immediate relief and will dry up the sores in 2 or 3 days.

Other prescriptions are as follows:

Add 3 oz. of camphor to 1 pt. of olive oil and dissolve by slow heat. This mixture occasions some pain when first applied but will soon afford relief.

In mild cases the following will be beneficial: zinc oxide ½ oz., zinc carbonate 30 grains, glycerin ½ oz., lime water to make ½ pt.

For sores which do not heal use: pure lard 5 oz., olive oil 5 oz., white wax 2½ oz., spermaceti 2½ oz., powdered gum

benzoin 12 oz.

For selenium poisoning under the fingernails, brush the ends of the fingers with 5 per cent. cocaine solution.

FIRST AID FOR GAS ASPHYXIATION OR ELECTRIC SHOCK

In line with its campaign to reduce the number of deaths in the mines of the United States, the Federal Bureau of Mines some time ago appointed a committee of eminent physicians and surgeons to develop an efficient method of resuscitation to be administered by miners or other persons to a fellow-workman overcome by electric shock or by gases in places which cannot be reached by a physician or surgeon in time to save life.

As a result of this committee's report the Bureau recommends the following procedure in rendering first aid to those in need of

artificial respiration.

The recommendations apply not only to men who are overcome by electric shock or gases in mines, but also to persons suffering from the effects of illuminating-gas poisoning or from electric shock anywhere. The recommendations are, therefore, of importance to many thousands of workmen:

In case of gas poisoning, remove victim at once from the gaseous atmosphere. Carry him quickly to fresh air and immediately give manual artificial respiration. Do not stop to

loosen clothing. Every moment of delay is serious.

In case of electric shock, break electric current instantly. Free the patient from the current with a single quick motion, using any dry non-conductor, such as a newspaper, clothing, rope, or board, to move patient or wire. Beware of using any metal or moist material. Meantime have every effort made to shut off current.

Attend instantly to the victim's breathing. If the victim is not breathing, he should be given manual artificial respiration at once. If the patient is breathing slowly and regularly do not give artificial respiration, but let nature restore breathing unaided.

If patient is unconscious, even if he appears dead, lay him on his belly with arms extended forward, turn his face to one side, remove false teeth, tobacco, etc., from his mouth and draw his tongue forward. This is important, the tongue must be brought forward and held forward.

Kneel, straddling patient's thighs, facing his head, and resting your hands on his lowest ribs. Swing forward and gradually bring weight of your body upon your hands and thus upon patient's back, then immediately remove pressure by swinging

backward. Repeat this movement about twelve times per minute without interruption for hours if necessary, until breathing has been started and maintained (see illustrations). One's own rate of breathing may be used as a guide to the rapidity of this movement. Artificial respiration should be a trifle slower rather than faster than natural breathing. If natural respiration stops after having once been started, begin again with artificial respiration instantly.



Inspiration; pressure off.



Expiration; pressure on.

In gas cases, give oxygen. If the patient has been a victim of gas, give him pure oxygen, with manual artificial respiration. The oxygen may be given through a breathing bag from a cylinder having a reducing valve, with connecting tubes and face mask, and with an inspiratory and an expiratory valve, of which the latter communicates directly with the atmosphere.

No mechanical artificial resuscitating device should be used unless one operated by hand that has no suction effect on the lungs. Use the Schaffer or prone pressure method of artificial respiration. Begin at once. A moment's delay is serious. Continue the artificial respiration. If necessary, continue 2 hours or longer without interruption until natural breathing is restored. If natural breathing stops after being restored, use artificial respiration again.

Do not give the patient any liquid until he is fully conscious. Give him fresh air, but keep his body warm. Send for the nearest doctor as soon as accident is discovered, advising him what has happened so that he will come prepared. If available,

and one has been properly instructed in its use, a hypodermic injection of strychnin or amyl nitrite is good, but these should never be given by anyone untrained in their application.

Nitrous Acid Poisoning.—It seems certain that brief exposure to small quantities of nitrous fumes is sufficient to produce serious and fatal poisoning. Air containing enough nitrous fumes to cause a feeling or irritation in the nose or air passages

is certainly very dangerous.

The symptoms of poisoning are characteristic, according to Dr. L. G. Irvine (Med. Journal of South Africa, Sept., 1915). At the moment of exposure they are slight. There is a sense of irritation in the nose and throat, and of constriction, and perhaps of pain, in the chest. There is headache, smarting of the eyes and coughing. The latter is a characteristic sign. But these immediate irritant effects may not be severe, and commonly pass off altogether in a short time. The man may feel quite well and may continue to work. He leaves the mine, has his supper perhaps, and goes to his room. Then, in from perhaps four to eight hours afterwards (very rarely later), acute symptoms suddenly come on, and progress with alarming rapidity. In a typical severe case there is marked and increasing distress in breathing, with coughing, and often severe pain in the chest. The cough is at first dry, and auscultation may at this stage reveal no moist sounds. But this condition is speedily followed by the expectoration of a copious frothy rather fluid blood-stained spit. The lungs become waterlogged, and auscultation now reveals copious moist sounds. There is cyanosis and marked dyspnæa and distress, followed, unless the case is promptly treated, and very often in spite of all treatment, by collapse, unconsciousness, and death within a few hours.

The typical sequence of symptoms in nitrous fumes poisoning is therefore this: (1) Initial symptoms of irritation occurring at the moment of exposure and usually comparatively slight. Nitrous fumes never, in our experience of ordinary gassing accidents, produce partial or complete unconsciousness at the time of exposure, as does carbon monoxide, although they may do so if present in massive amounts, and cases of rapid death from the concentrated fumes of burning explosives may be partly due to this cause. (2) A latent period of several hours duration, during which the patient may, and commonly does, feel quite well. (3) The sudden onset after that interval of acute symptoms, due to a rapidly progressive inflammatory codema of the lungs. The appearance of this well-marked symptom-

sequence is of great diagnostic significance.

The post-mortem signs are also definite. There is an intense injection of the trachea and bronchi, which is characteristic. The lungs are intensely edematous, often enlarged and tense with cedema. A copious frothy blood-stained fluid exudes from them on section, and may be seen to occupy the air passages. There may be patches of incomplete consolidation, sub-pleural hæmorrhages may be observed, and blood-stained fluid in the

pleural cavities or the pericardium. The right heart and the great thoracic and abdominal veins are engorged with dark, thick, sometimes almost tarry, blood. The abdominal veins especially are often very greatly distended.

From what is said, it seems probable that a number of the deaths of workers in powder plants ascribed to pneumonia are really due to nitrous- and nitric-fume poisoning and greater care in avoiding these gases should be exercised than is ordi-

narily used.

Where it is believed that dangerous exposure to nitrous acid fumes has occurred, an emetic seems advisable, copper or zinc sulphate being commonly employed, following this by a dose of sal-volatile. A hypodermic of apomorphin may be given to produce the same effect, but this should be given by a physician and either preceded or followed by an injection of strychnin or pituitrin.

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A	Audminum, dovormination of 041
,	electrolytic production of. 586
	gravimetric factors 338
Abbé mill	impurities in 514
Abbreviations	prices, average55
	production statistics 57, 58
Accidents, first aid in 632	properties
Acetones, defined 627	Alundum, properties of 442
Acetylene, action of, on metals. 214	Amalgamating pan 355
generation of	Amalgams, heat of formation of, 301
Acid-resisting alloy, composi-	Ammonia, determination of 353
tion	generation of 184
Acids, action of, on metals 214	gravimetric factors 343
hydrochloric, density of 122	specific gravity of 126
hydrofluosilicic, density of. 127	Anaconda zinc process 591
miscellaneous heats of for-	Analysis, qualitative, acids 284
mation 300	qualitative, bases 270-283
nitric acid, density of 123	Analytics, fundamental equa-
organic, defined 627	
qualitative analysis for 284	Angle of nip
sulphuric, density of 114	Annealed copper standard 165
Actinium, properties of 290	Annealing, for chains 468
Acsolling, definition of 493	Annuities, formulas for 18
Adiabatic expansion, equation	tables 20
for	Anode potentials 314
	Anodes, analyses
Admiralty metal, British, com-	Anodes, analyses 583
position of 498	converter vs. furnace re-
U. S. bronze 499	fined 581
Agitators 390, 391, 392	insoluble-anode materials, 584
Aich's metal, composition of 498	slime analyses 584
Air available for flotation 409	tanks 582
combustion limits in 437	Anthracite, analyses of 431
composition of	commercial, sizes of 434
compressed-air tables. 474–480	Antidatas aranida
	Antidotes, cyanide 635
solubility of, in water 215	general634
Ajax plastic bronze, composi-	Antifriction metal, composition
tion of 498	of 498
Akerman's table of total heat in	Antimonides, heat of formation, 297
slags 547	specific heats of 207
Akins classifier	Antimony, alloys of 499-502
Alcohols, definition 626	in blast furnace 528
Algebra, elementary formulas 16	determination of 351
Alkali-resisting metal, compo-	electrolytic production of. 587
sition	gravimetric factors 338
Allotropy of metals 510	impurities in 515
Alloys, general table of 497-502	prices, average 55
heats of formation 302	properties
liquid (see "Gallium") 260	Apothecaries' measure, table of, 8
properties at extreme tem-	
peratures 510	Aqueous vapor, tension of, 106, 110
Alphabet, Greek	weight per cubic foot 107
Altitude, barometrio pressure,	Arches, construction of 457
effect on 112	firebrick in 440
Alumina in slags 528, 539	Arcs, sparking distances 169
Aluminates, heat of formation. 301	Areas, formulas for
specific heats of 206	of polygons
Aluminum, alloys of 497, 502	
consumption of	Argentan, see "Berlin Argentan."
detection of 270	Argon, generation of 185

Argon, properties	256	\mathbf{Blast}	furnaces,	iron-furnace	
Arsenic, properties of			practice	• • • • • • • • • • •	609
Arsenides, heat of formation	297	jac	ket water r	equired	552
specific heats of		lea	d furnaces.	• • • • • • • • • • •	568
Arsine, generation of	185	the	ermochemis	try of	612
Asbestos, properties of				ing data, 551,	
Ashberry metal, composition of,		Ē	lags		52
Asphyxiation, first aid in	636	Bleedin	g, treatmen	t of	632
Assay fluxes	323	Blende	effect on l	plast furnace,	
ton, definition of	7	Blowing	r machiner	y, for copper-	-
Atom, structure of 239,	240	2510 (1222)	emelting	···········	550
Atomic numbers 242,	243	g A 1	narel notes	•••••	490
mointe	254 254	. tos	ting	• • • • • • • • • • • • • • • • • • • •	491
weights		Divo	oung		570
Auer metal, composition of	502	Diue po	wder analy	ses	
Augustin process, description	493	Diue vi	trioi analys	es, typical	583
Austenite, definition of	261	Bomng	points, ami	monia	132
Avogadro's law	239	cai	pon gioxide	э	133
		01 (elements		254
В		of:	metals	131,	132
		of	nitric acid.		133
Babbit, composition of	498	of :	non-metals.		132
Bag-house data	600	OTS	ganic bodies	3 140,	629
Balance sheet, iron furnace	615	of :	salts	216	-23
steel converter 613,	614	sul	phur dioxid	le	132
Ball mill 355,	357			132, 133,	134
Ball-Norton magnetic separator	385	Bomb		r, standards	
Balling's slag tables 539-	-542				307
Barium, detection of	271	Bombs.	incendiary		192
determination of 345,	346	Bond in	terest form	ula	
gravimetric factors	338	Rorates	heat of fo	rmation	297
proportios	257	201200	onific heats	of	20
properties	#01 529	Boron	detection of	f	280
in slags		DOIOII,	uevecuou o	ctors	338
Barometer, altitude effect					257
correction for capillarity		Boss pr	phermen	······································	493
for gravity	112			ription	
corrections for temperature	110			hardness	199 78
Bartlett table	385	Doyles	12.W	• • • • • • • • • • • • • • • • • • • •	
Bases, qualitative analysis for	201	Dramey	process		60
Batteries, e.m.f. of	112			of	498
Baumé, conversion to specific	490			bath	310
gravity 113,		108	a or sine in	melting	593
Bauxite, analyses of	587	NOS	der for		498
properties of	443	Drick, I	merting poil	nts	447
Bearing metals, composition of.	498	ior	cement kil	ns	449
Bell metal, composition of	498	ior	gas retorts	•••••	448
Belt conveyor, capacity	458	Ens.	ipes of	• • • • • • • • • • • • • • • • • • • •	439
Berlin argentan, composition of,	498	Buckra	ying, hints	on	44]
Beryllium, detection of	273	Runnel	i, hardness	numbers	198
electrolytic production of	587		ests	••••••	197
properties	257			al notes	608
Bessemer process, description of	493	Briquet	ting proces	8 e5	608
Betts process, description	493			ition of	498
Bilharz table	385	British	Columbia	Copper Co.,	
Bismuth, alloys of 498,	502		costs of s	melting at	551
detection of	271	sm	elting opera	tions	551
electrolytic deposition of	587	British	thermal un	it, definition	
gravimetric factors	338	Ÿ	of		3
impurities in	515	Brittler	ess of meta	ls	193
_ properties	257	Bromid	es, heat of	formation	298
Bisulphates, heat of formation,	301	Spe	ecific heats	of.,	206
Bituminous coal, analyses of	431			on of	18
Blaisdell machinery	389	gra	vimetric fa	ctors	338
Blake crusher	355			•••••	258
crushing with	358	Bronzes	o compositi	on of 498,	
largest	365			iption	390
Blanket-table data	401	Y =	ower data		428
Blast furnaces, balance sheet,				of	632
iron furnace	615	Bryan	mill		35
copper smelting	549	Buddle	Dodds		386
gases, analyses of	552	Buildin	g, general n	otes on, 480-	
			57 57V- WI M		

Dulle medalise		o	400
Bulk modulus	194	Company company	492
Bull dog, properties of	442	Cement kilns, brick for	449
Bullion-mould sizes	607	Cementite, definition of	261
Demonina to ble			
Bumping table	386	Centigrade, temperature scale	3
Bunker Hill screen	390		502
	633	detection of	272
Rust filton	390		587
Burt filter	_		
Butters filter	390		258
		C. G. S. units	10
		Chains, annealing	468
${f c}$			467
•			
			611
Cadmium, detection of	271	Charges, crucible, for assays	326
electrolytic production of	587		356
flue dusts commercials			374
flue dusts, composition	573		
gravimetric factors	339		603
properties	258	Chinese bronze, composition of,	499
Caesium, detection of	271		300
cacation of the state of			
	339		203
properties	258	Chlorine, determination of	352
Calcium, detection of	271	generation of	185
determination of	345		339
	_		
electrolytic production of	587		259
gravimetric factors	339		205
properties	258	Chromax bronze	502
Calculus, elementary formulas.	50		443
Caller concluded to the concluded.			
Callow cone	390		502
screen	390	detection of	272
tank	390	determination of	347
Calorie, definition of	4		587
Calculation of the second of t			
Calorific power, liquid fuels, 429-			619
Calorimeter, standards for	307	gravimetric factors	339
Calorized metal, see "Insulumi-			259
num."			440
	400		
Camelia metal, composition of.		Circular measure	9
Canvas table, description. 386,	387	Classifiers 389-	392
general data		Cleaning metals by electrolysis,	317
Capacity, measures of		Clevenger's formulas for pulp	-
		Clevenger a formulas for purp	400
of tanks	422	constants	
Capillarity, barometric correc-		Coagulants, slime	421
tion for	111	Coal, analyses of 431,	434
Capillary constants of metals	145	commercial sizes	434
	140		
Carbides, composition of metal-		grate area	400
lic	618	production of U.S	57
heat of formation	298	sampling	331
iron	261	Coal-dust firing in reverbera-	
Carbon brick, laying	443	toriog	557
Carbon blick, laying		tories	
Carbon dioxide, determination.	287		436
generation of	185	Cobalt, alloys of	502
gravimetric factors	339		272
Carbon monoxide, generation of	185		349
	100		
Carbonates, decomposition	904		311
temperatures	306		339
heat of formation	299	properties	259
specific heats of	205		576
Cand concentration			
Card concentrator	386		489
Carkeek's slope tables for laun-			195
ders	402	of rigidity	194
Carnotite ore treatment	592	Coercivity, definition	234
Carpentrywork, cost of	486		57
		Coke, production, U. S	
Carpet-table data	401	sampling	331
Cast projectiles	508	Coinage alloys, composition of,	
Castings, shrinkage of	610	498,	499
Cathode potentials	314	standards	16
		Coine males of	
Cattermole flotation process	406	Coins, value of	15
Caustic potash, resistivity of		Color scales for temperature	453
solutions	162		272
specific gravity of solutions		Combination, heats of 291-	
Caustic soda, specific gravity of	·		
	105	Combustion, efficiency of, in	400
solutions	127	engines	438

Combustion, limits of 437	Conner exertimetric factors 220
Compusion, names of, 457	Copper, gravimetric factors 339
oxygen required for 432	impurities in 514, 515
temperatures 432	leaching604
Compounds, chemical and com-	losses in slag 558
mon names of 320	prices, average 53
Compressor formulas 474-480	production statistics 57, 64
Concentration, machinery used	properties
Concentration, machinery used	refining consoits 7/
in	refining capacity
specific gravities, minerals, 181	reverberatory refining 579
Concentrator, canvas table data, 401	sheet prices 54
power requirements 393, 394	smelting capacity of the
vanner data 398-400	U.S 72
water requirements 395-397	
Concrete, costs of 486	wire resistances 167
Condensation of dust and fume, 598	works construction cost 481
Conductivity, electric, of alloys 157	Corning table 385
annealed copper stand-	Corrosiron
ard	Cosines, table of 44
20nnon — inc 40 hla 167 160	Costs of metallurgical construc-
copper-wire table 167, 168	Costs of metalidigical constitue
of electrolytes 161	tion
at high temperature 158	Cotangents, table of 46
of metallic oxides 164	Cottrell process 599
of metals 156, 157	Cowper-Cowles iron-refining
of molten metals 159	process 592
	Crilley flotation patent 406
of ore-forming materials 624	Chitical passages of mass
of oxides	Critical pressures of gases 183
relation to heat conduc-	Critical temperatures, of gases, 183
tivity	of metals 236
wires, miscellaneous, 168, 169	Cross sills, size of 381
Conductivity, heat, general	Crosses (pipe fittings) 463-466
	Crowder flotation patent 406
tables 146, 148	Christia charges for second 200
of refractories 455–457	Crucible charges for assays 326
relation to electric 156	Crucibles, graphite 330
Cones, Seger 450	highly refractory 329
Conkling magnetic separator 386	Crushed stone, voids in 364
Conservation of energy, law of, 239	Crushing, Chile mill 374
of matter, law of 239	description of types of ma-
	description of types of ma-
Constantan, composition of 499	chinery 355
resistance of 168	general notes on 355
Construction, general notes on,	gyratories
480–487	Hardinge mill 376
Consumption statistics of alu-	slow-speed chilean 374
minum 58	stampmilling
	tubemilling 372-373
of iron ore	Cryohydrates144
of lead 59, 60	Crystolon, properties of 444
of tin	Cube roots, table of 32
of sinc	Cubes, table of
Converters, sizes of 562	Cupel absorption 327
Converting, at B. C. smeltery 562	Cupellation 327–329
	Cupolision of
	Cupola, copper, elimination of
at Great Falls 561	impurities 579
iron-converting data 610, 614	iron, charges for 616
temperatures of 547	Cupromagnesium, composition
Conveyer capacity 458	of 499
Cooling mixtures 144	Current losses, copper refining. 580
Copper, alloys of 498-502	Curvature of wire ropes over
annealed copper standard, 165	pulleys 471
blast furnaces 549	Cyanates, heat of formation of, 294
casting copper analysis 583	Cyanidation, Dorr thickener
consumption statistics 63	data 426
converting 561	general notes 419-428
cupola refining 579	machinery for 389
detection	pulp constants
determination of 350	alima acamilanta
	slime coagulants
electric smelting 560	specific gravity of solutions 421
electrolytic refining, see	tank capacities 422
"Electrolytic Refining."	Cyanide ecsema, cure 635
electroplating bath 310	heat of formation of 294
fusing currents for 168	plant, cost of 481–483
CALLOTTAN TATELLE TAG	humani 0000 01

Cyanide eczema, poisoning,	Dorr agitator 390
antidotes	classifier
precipitation	thickener data
Cyanogen, gravimetric factors, 340 generation of 185	Drop of stamps
	Dry measure, tables 8, 9
D	Ductility of metals
Daltan's law 920	Dulong and Petit, law of 239 Dumoulin process, description
Dalton's law	of
De Bavay flotation process 408	Duquesne blast-furnace practice 611
Decomposition temperatures of	Duralumin, composition of 499
carbonates	Duriron, composition of 499, 506 insoluble anodes from 584
of sulphides	Dust condensation 598
Decomposition voltages 315	Thiessen washer 617
Definite proportions, law of 239	Dwight-Lloyd roaster, work of, 517
Dehne filter press	${f E}$
sulphates 302	2
Deister table 386	Ecsema, cyanide, cures for 635
Delta metal, composition of 499	Edge runner
Density of alkaline solutions 127 ammonia 126	Elastic constants of solids, 194, 489 Elbows, standards for 461-466
Baumé	Electric shock, first aid in 636
gangues 181	Electric smelting, of copper 560
gases	of iron 618, 620
hydrochloric acid 122 hydrofluosilicic acid 127	of tin
liquids (general) 171	Electrical units, C. G. S 10, 11
mercury 176	practical 11, 12, 77
minerals 178	Electrochemical equivalents,
nitric acid	series of the elements 315
ores	Electrolysis, cleaning metals by, 317
saline solutions 128-131	decomposition voltages 309
solids	etching by
sulphuric acid	oxidation by
units of	Electrolytes, analyses of copper,
water, various tempera-	583, 581
tures 175–176	density of saline 128, 131
Deposition by immersion 317 (See also Electroplating.)	resistance of 162-164 specific gravity of saline,
Depreciation, formulas for. 18, 25	128–131
tables 20	starting-sheet 581
Desulphatization, temperature	Electrolytic refining, aluminum, 586
of	antimony
Dewrance metal, composition of 499	bismuth 587
Diehl process, description of 493	cadmium 587
Dielectrics, resistivity of 160, 161 Differential calculus 50	calcium
Differential calculus 50 Diffusion of gases, law of 239	cerium
Diffusivity of heat 454	converter anodes 581
Dilution, heats of 307	copper 580-585, 588
Dinas brick, properties of 444 Ding's magnetic separator 386	current losses 580 elimination of impurities, 582
Ding's magnetic separator 386 Disintegration, chart for radio-	flow sheet, copper 580
elements 247	gold
Disk crusher 358	insoluble-anode tanks 582
crushing with 367	iron 311, 588, 592 lead 586, 589
Dissociation temperatures of compounds 524	lithium 589
tensions for sulphates 304	magnesium 589
Distillation products of coal tar, 436	potassium 589
Dodds buddle 386	silver
Dodge crusher	starting-sheet electrolyte 581
Dolomite, properties of 444	strontium 590

Electrolytic refining, tin 590	First aid, electric shock 636
uranium 590	poisoning 634, 635
zinc	selenium poisoning 636
Electromagnetic separation, 236, 237	Flames, residual atmosphere
Electromotive force, of batteries 112 of metals in solution 316	from
of thermoelectric couples 171	Flotation
Electron, properties of 245	Flow of gas in pipes 473
Electroplating baths 310-313	of heat 152, 154
Electrostatic fume precipitation 599	of water in pipes 472
separation 165, 387	Flue dust, anode reverberatory,
units 10–12, 77	analyses 583
Elektrometall furnace 620	copper refinery, analyses 583
Elements, atomic weight 254	wire-bar reverberatory,
boiling points 254	analyses
electrochemical equiva- lents 254, 255	specific heats of 206
melting points 254	Fluorine, gravimetrio factors 340
periodic table 242, 243	properties 260
specific heats 202	Fluorspar in slags 528
symbols 254	Fluxes, assay 323, 325
valence	for soldering and welding 511
Elianite 502	Fontaine-Moreau's bronze 499
Elmore flotation process 407, 408	Force, units of
Elsner's equation	Foreign measures
End-bump tables 386	money
Energy, units of	Formation, heats of 291-304
Erbium, detection of 273	temperatures of slags,
Esperanza classifier 391	525, 533-537
Etching, reagents for 333	Foundations, allowable pressure
Ethane, generation of 185	on
Ethers, definition	France screen
Ethylene, generation of 185 Eureka, wire resistance 168	Freezing mixtures 144 Froment flotation patents 407
Eureka, wire resistance 168 Evaporation, latent heat of 199	Frue vanner
Evaporative power, liquid fuels 429	Fuel oil, calorific power 429
Everson flotation patent 406	Fuels, analyses of
Expansion, coefficients of 195-197	calorific-power formulas 435
Eye injuries, treatment of 632	combustion temperatures, 432
F	gas analyses 431, 435
-	general subject
Factors, gravimetric	kindling temperatures 435 liquid fuels 429
Fahrenheit temperature scale 3 Failure of metals 192	oil analyses 433, 434
Faraday scale of permeability. 236	oxygen required for com-
Ferraris table	bustion
Ferrite, definition of 261	Fuller-Lehigh pulverizer 356
Ferro-alloys 502, 503, 504	Fume, composition of zinc 571
Ferrochrome manufacture 619	condensation 598
Ferrocyanides, heat of forma-	Functions, trigonometric 28
tion of	values of
Ferromanganese production, U.S57	ous, analyses 544
Fettling, reverberatory practice 553	Furnaces, copper blast, typical, 549
Fibrox, properties of 444	electric iron
Film-sizing tables 387	steel
Filter press 390, 391	gases from 552
Filters 391, 392	jacket water required 552
Firebrick, circles turned with 440	Fusible metal, see Darcet's,
melting points 447	Guthrie's, Lipowitz's,
shapes of	Lichtenburg's, New- ton's. Onion's, Rose's
in walls of given size 441 Fireclay, analyses 443	and Wood's metal.
heat conductivity 444	Fusing currents for copper wire, 168
properties of 443	other materials 169
(See also Refractories.)	Fusion, see also "Melting
First aid, accidents 632	Points."
asphyxiation	latent heats of 200, 201, 210
cyanide poisoning 635	total heats of 210, 211

\mathbf{G}		387
Gages, sheet-metal 512, 513	Hardinge mill, description of grinding in	356 376
wire	Hardness, Bottone's scale	199
Gallium, detection of 273	Brinnell numbers	199
properties	test	197 197
Ganister, properties of 445	of minerals 178-	-181
Gardner crusher 356	Moh's scale	198
Gas fuels, analyses of 431, 435 inflammability limits 436	Hardware metal, composition of Harmonic motion, equation of,	500 75
kindling temperatures 435	Harz jig	387
residual atmosphere from. 437	Hayden process, description of,	493
Gas retorts, brick for 449 Gases, adiabatic expansion of . 75	Heat, conductivity, general tables 146,	148
Boyle's law	laws of 152,	
critical temperatures and		454
pressures	of dilutionemissivity	307 454
generation of 184	etching by	336
lethal amounts of 191	of formation 291-	
molecular weight of 182 solubility of, in water 215	latent heat of evaporation, of fusion	200
specific gravity 182	loss in gas mains	612
specific heats of 209, 210	loss by radiation	453
toxic	of solution	304 -210
Gay-Lussac, law of 239	total, of fusion 210-	-211
Geometry, analytic 48	in slags	547 3
German shell analyses 507 German silver, composition of, 499	units, definition of Helfenstein furnace	622
Sheffield type 501	Helium, properties	260
wire resistances 168 Germanium, detection of 273	Hitches, in ropes	469 625
Gilpin County table 386	Homologous series	020
Glucinum, detection of 273	494,	
properties (see beryllium). 257 Gold, detection of 273	Horwood flotation process Huff separator	408 307
determination of, in plati-	Humidity tables	104
num 278	Hunt filter	391
electrolytic production of 588 electroplating bath 311	Hunt's process, description of Hunt and Douglas process, de-	494
gravimetric factors 340	scription of 494,	604
production statistics, 57, 67, 68	Huntington-Heberlein roaster,	717
proof, preparation of 321 properties 260	work of	517 356
Golden Gate concentrator 386	Hyde flotation process	408
Goyder flotation process 407	Hydraulic bronze, composition,	
Grate area for coal 437, 438 Gravimetric factors 338	Hydrides, heat of formation Hydrocarbons, chemistry of	296 625
Gravity, barometer correction	heat of formation of	303
for	Hydrochloric acid, density of generation of	122 185
Grinding in Chile mills 374	resistivity of	162
in grinding pans 373	Hydrocyanic acid, generation of	186
in Hardinge mill 376 in tube mill 372, 373	Hydrofluosilicie acid, specific gravity of solutions	127
Gröndal separator 387	Hydrogen, generation of	185
Gun metal, composition of 499	gravimetric factors	340
Guthrie's metal, composition of 499 Gutzkow's process, description	overvoltagephosphide, generation of	314 186
of 493	reduction by	305
Gyratory crusher, breaking	selenide, generation of	186
with	sulphide, generation of telluride, generation of	186 186
•	Hydrometers, Baumé table	113
H	constants for	112
Hall process	Hydroxides, heat of formation of	
Hallett table 387	Hygrometric tables	77

I	Jig, water used in, 387-389, 402 Johnson vanner 388
Ignition temperatures, gaseous	Source Assuret 900
mixtures 435	K
metallic sulphides 523	
Imlay concentrator 386	Kaisersinn, see "Britannia."
Immersion, deposition of metals	Kakodyl, generation of 186
by	Kelly filter
Impact screen	sion
Imperial screen	Kent roller mill
Incandescence, temperatures of,	Ketones, definition 627
in roasting 523	Kieves
Incendiary bombs	Kilogram, definition of
Indium, detection of	weight of, in pounds 7 Kindling temperatures, table of 435
Ingot-mould capacity 607	King screen 391
Injuries, treatment of 632	Kinkead mill 356
Insuluminum	Kirby's table, ore in place 177
Integral calculus	Kiss process, description of 494
Interest, formulas for 18, 23 tables 20	Knots, how to tie
tables	Krypton, description of 262
specific heats of 206	Kunheim metal, composition of 505
Iodine, gravimetric factors 340	·
properties 260	${f L}$
Ionium, properties of 290	T 1 4 004
Iridium, detection of	Laboratory screen sizes 384 Lane mill, description 355
properties	Lane mill, description 355 grinding in 374
blast-furnace balance sheet 615	Lanthanum, occurrence 262
practice 609	Latent heat, definition of 4
briquetting 608	Latent heats of evaporation 199
carbon, compounds with. 261	of fusion 200, 201, 210, 211
converting data 610, 614	Laughton flotation process 407 Launders, moving sand in 404
cupola charges	Launders, moving sand in 404 slope of 402
determination of 346	water-carrying capacity 403
electric-furnace types, 618, 620	Leaching, copper 604
electrolytic production of 588	Lead, alloys of 497-501
electroplating baths 311	blast furnaces
ferrochrome manufacture. 619 gravimetric factors 340	consumption statistics 59, 60 detection of 274
heat content of iron 610	determination of 350
magnetic properties. 234-236	electrolytic refining data,
Monell process 614	586, 589
ore, see "Iron Ore."	electroplating bath 311
permeability 234-236	gravimetric factors 340
properties of 261, 273	impurities, effect of 515 pattinsonizing data 566
pure iron defined 515 in slags 525	prices, average for 10 years, 54
Thiessen washer 617	production statistics 57, 59
works, cost of 481	products of smelting, analy-
Iron ore, consumption of, in	ses
U. S 69	properties of
production in U.S 57, 69	roasting lead ores 516 smelting capacity, U.S 62
Isbell table	softening, typical analyses, 566
Ivanium alloy	steam, effect on molten
_	lead 565
J	type slags
Tooket mater for furnesses	works, cost of 481, 483
Jacket water for furnaces 552 Jacoby metal, composition of 500	sine table for 30-ton kettle, 566 Le Blane process, description of, 494
James concentrator 388	Lethal amounts of gases 191
Japanese bronse, composition,	Lichtenberg's alloy, composi-
499, 505	tion of 499
Jaw crusher, crushing with 357	Light, velocity of
Jeffrey swing-hammer crusher 357	wave length of
Jerking table 386	Lignite, analyses of 431

Lime, as a refractory 445	Masonry, allowable pressures
in slags 527, 532 Linear expansion, coefficients of,	on
195-197	cost of construction 484 Matte smelting, factors for 538
Linear measure, tables of 4, 5	specific gravity of mattes. 533
Lipowitz's metal, composition, 500	sulphur affinity in 532
Liquids, expansion of 197	Maxton screen
specific gravity of 171	Measure, capacity, tables of 8, 9
Litharge, fluxing oxides with 326 Lithium, description of 262	circular, tables of 9 linear, tables of 4, 5
detection of	miscellaneous units 10
electrolytic production of 589	square, tables of 6
gravimetric factors 340	time 10
Log washer	Mechanical engineering 458
Lohmannizing, description of 494 Longmaid-Henderson process 602	Melting point, affected by pressure
Losses in copper slags 558	sure
Low temperatures, effect on	of firebrick
tensile strength 195	of organic bodies 140
electric conductivity 157	of oxides
Luce-Rosan process, description of 494	of salts
of	Mendeleef's table 242, 243 Mercury, consumption of 58
Dumis value,	description of
M	detection of
	gravimetric factors 342
Macadamum, composition of 505	prices, average
MacArthur-Forrest process, description 494	production statistics 57, 58 smelting 577
McDonald's table, ore in place, 177	smelting
Mackensie's alloy, composition 500	Metallography, reagents for 333
Macquisten process 408	Metals, acetylene, action of, on
Magnalium, composition of 500	metals
Magnesite, properties of 445, 456	acids, action of, on metals. 214
(See also Refractories.) Magnesium, description of 262	boiling points of
detection of	bulk modulus 194
determination of 345	capillary constants 145
electrolytic production 589	coefficient of rigidity 194
gravimetric factors 340	conductivity, electric. 156, 159
in slags 527, 532 Magnetic separating plant cost, 481	heat
Magnetic separators, Ball-Nor-	ductility
ton 385	etching 333
Conkling 386	gravimetric factors 338-343
Dings	latent heat of fusion,
Grondal	200, 201, 210 magnetic susceptibility 234
Wetherill389	impurities in 514
Magnetic units, C. G. S 10	malleability 193
Magnetism, "see Permeability" and "Electromagnetic	molten, conductivity of 159
and Electromagnetic	permeability
Separation." Magnolia metal, composition of, 500	plasticity
Malleability of metals 193	price statistics 53-56
Manganese bronze, composition	production statistics 57-74
of 505	resistivity, thermal 148
Manganese, description of 263	shrinkage of, on solidifying 238
detection of	solubility of, in acids 214 specific heats 202
gravimetric factors 341	surface tension of 145
in slags 525	susceptibility, magnetic 234
Manganin, composition of 500	tensile strength 194, 195
wire, resistance of 168	total heat of fusion 210
Mannheim gold, composition of 500 Marathon mill	toughness
Marcy mill	Metameric compounds 627
Mariotte, law of	Meter, definition of
Marriner process 494	length of, in feet 5
Martensite, definition of 261	Methane, generation of 186

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Mill recovery, calculation of 418	Nitrogen, determination of 353
Mills, construction notes 480-487	generation of
cost of	gravimetric factors 341
Miller process	Nitrogen peroxide, generation
Milling, canvas table data 401	of
power required 393, 394	Nitrous oxide, generation of 186
vanner data 398-400	Nitrous acid poisoning638
water required 395-404	Noncorrosive alloys 505
Minerals, composition of 178-181	
density of	0
hardness of 178–181	•
Minerals Separation process 407	Oils, calorific powers of 429-431
Misch metal, composition of 505	composition of fuel oils,
Modulus, bulk	401 400 404
Young's	for flotation 409, 415
Moebius process, description of 494	Olary ores, treatment of 595
plant cost	Oliver filter 392
Moh scale of hardness 198	Onion's alloy, composition of . 500
Moisture, in atmosphere 76	Optical pyrometers 593
in fuels	Ores, conductivity (electric) of, 624
retained by ore 404	consumption of iron ore in
Molecular weights of salts, 216-233	U. S 69
Molybdenum, description of 263	production of iron ore in
detection of	U. S 57, 69
	sampling of
Monel metal, composition of 500	screen analyses of 612
Monell process, heat balance 614	Organic chemistry 625
Money, table of values 15	Osmium, description of 264
Moore filter press 391	detection of
Morin's Chinese bronze, compo-	Overstrom table 388
sition of 500	Overvoltage 314
Mortar-block data 382	Ovoca classifier 392
Mosaic gold, composition of 500	Oxidation agents in assaying 324
	by electrolysis:
	wet reagents
Multiple proportions, law of 239	Oxides, fluxing with litharge 326
Multiple vs. series refining 585	heat of formation of 293
Muntz metal, composition of 500	heat of formation of 293 melting points of 446
Muntz metal, composition of 500 Murex process	heat of formation of 293 melting points of 446 oxidation of 306
Muntz metal, composition of 500 Murex process	heat of formation of 293 melting points of 446 oxidation of 306
Muntz metal, composition of 500 Murex process	heat of formation of 293 melting points of 446 oxidation of 306 reduction temperatures of, 305
Muntz metal, composition of 500 Murex process	heat of formation of 293 melting points of 446 oxidation of 306 reduction temperatures of, 305 resistivity of 164
Muntz metal, composition of 500 Murex process	heat of formation of
Muntz metal, composition of 500 Murex process	heat of formation of
Muntz metal, composition of 500 Murex process	heat of formation of
Muntz metal, composition of 500 Murex process	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of , 500	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of , 500 Nickel, alloys of 502	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of , 500	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of , 500 Nickel, alloys of 502	heat of formation of
Muntz metal, composition of	heat of formation of
Muntz metal, composition of . 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of 500 Nickel, alloys of 502 description of 263 detection of 263 detection of 275 determination of 349 electroplating bath 311	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of , 500 Nickel, alloys of 502 description of 263 detection of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of , 500 Nickel, alloys of 502 description of 263 detection of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of 500 Nickel, alloys of 502 description of 263 detection of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of 500 Nickel, alloys of 502 description of 263 detection of 263 determination of 263 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining,	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of 500 Nickel, alloys of 502 description of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of 500 Nickel, alloys of 502 description of 263 detection of 263 determination of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of , 500 Nickel, alloys of 502 description of 263 detection of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544 smelting data 576	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of , 500 Nickel, alloys of 502 description of 263 detection of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544 smelting data 576	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of , 500 Nickel, alloys of 502 description of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544 smelting data 576 Niobium, see "Columbium."	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of 500 Nickel, alloys of 502 description of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544 smelting data 576 Niobium, see "Columbium." Nip, angle of 366	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of 500 Nickel, alloys of 502 description of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544 smelting data 576 Niobium, see "Columbium." Nip, angle of 366 Nissen stamps 357	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of 500 Nickel, alloys of 502 description of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544 smelting data 576 Niobium, see "Columbium." Nip, angle of 366 Nissen stamps 357 Niter, oxidizing sulphides with 325	heat of formation of
Muntz metal, composition of	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of 500 Nickel, alloys of 263 description of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544 smelting data 576 Niobium, see "Columbium." Nip, angle of 366 Nissen stamps 357 Niter, oxidizing sulphides with 325 Niton, properties of 290 Nitrates, heat of formation of 301	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of 500 Nickel, alloys of 502 description of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544 smelting data 576 Niobium, see "Columbium." Nip, angle of 366 Nissen stamps 357 Niter, oxidizing sulphides with 325 Niton, properties of 290 Nitrates, heat of formation of 301 specific heats of 205	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of , 500 Nickel, alloys of 263 description of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544 smelting data 576 Niobium, see "Columbium." Nip, angle of 366 Nissen stamps 357 Niter, oxidizing sulphides with 325 Niton, properties of 290 Nitrates, heat of formation of 301 specific heats of 205 Nitric acid, specific gravity of 123	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of 500 Nickel, alloys of 502 description of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544 smelting data 576 Niobium, see "Columbium." Nip, angle of 366 Nissen stamps 357 Niter, oxidizing sulphides with 325 Niton, properties of 290 Nitrates, heat of formation of 301 specific heats of 205 Nitric acid, specific gravity of 123 anhydride, generation of 186	heat of formation of
Muntz metal, composition of 500 Murex process 408 Mushet steel, composition 505 N Neodymium, detection of 275 properties of 263 Newaygo 391 Newton's alloy, composition of , 500 Nickel, alloys of 263 description of 263 detection of 275 determination of 349 electroplating bath 311 gravimetric factors 341 impurities in 515 production statistics 57 salt from copper-refining, analyses 583 slags, blast-furnace 544 smelting data 576 Niobium, see "Columbium." Nip, angle of 366 Nissen stamps 357 Niter, oxidizing sulphides with 325 Niton, properties of 290 Nitrates, heat of formation of 301 specific heats of 205 Nitric acid, specific gravity of 123	heat of formation of

Peirce-Smith process, descrip-	Power, cubes, table of
tion of	Dorr thickener
tion of	transmission 428
Pendulum, seconds, length of 10	units of
Pendulum, torsional, period of, 75	Praseodymium, see "Neody-mium."
Periodic law	
table	Precipitates, properties of, 344–354
Permeability, magnetic 234-236 of refractories 455	Precipitation of metals by elec-
Permutation, laws of	trolysis
Pewter, composition of 500	Preservatives, effectiveness of
Phonoelectric wire, see "Silicon	wood
Bronze."	Pressure, critical, of gases 183
Phosphates, heats of formation, 300	effect on boiling point, 132-134
specific heats of 206	Price, of aluminum, yearly aver-
Phosphides, heat of formation, 297	ages
Phosphine, generation of 187	antimony, yearly average. 55
Phosphor bronze, composition of 501	copper, monthly averages. 53 wire and sheets 54
Phosphorus, determination of 352	lead, monthly averages 54
gravimetric factors 341, 342	platinum, yearly average 55
properties of 265	quicksilver, yearly average, 55
Physics, fundamental laws 75	spelter, monthly averages. 56
Pig-iron output	tin, monthly averages 56
Pinchbeck, composition of 500	zinc, monthly averages 56
Pinder concentrator 388	Production statistics of arsenic, 57
Pipe fittings, standards for, 461-466	of aluminum 57, 58
Piping, formulas for	of coal
Placer sands, magnetic separa-	of copper 57, 64
tion	of ferromanganese 57
Plants, metallurgical, construc-	of gold 57, 67, 68
tion 480	of iron
costs of	ore 57, 69
Plastic bronze, composition of 500	of lead 57, 59
Plasticity of metals 193	of nickel
Plates, slope of, in Australian mills 405	of petroleum 57, 69 of quicksilver 57, 58
Platine, composition of 501	of silver 57, 65, 66
Platinoid, composition of 501	of spelter 57, 62
wire resistance 169	of tin
Platinum, cupellation of 327-329	of zinc 57, 60, 61, 62
description of	Progressions, mathematical 17
detection of	Proof gold, preparation of 321
determination of 278 electroplating bath 312	Proof silver, preparation of 322
electroplating bath 312 gravimetric factors 342	Pulley, curvature of wire ropes over 471
parting 328, 329	Pulp constants 420
world's production of 68	Pumps, formulas for 472
Poison gases 187–191	Punched-plate screens 385
Poisons and antidotes, cyanide. 635	Pyritic slags, typical 539
general 634	Pyrometers, color scales 453
Polygons, areas of 26	Erhard and Schertel 452
Polyhedrons, areas of	metallic salts
Polonium, properties of 290	optical
Porosity of refractories 455	Pyrophoric alloys
Potassium, description of 265	Pyschrometric tables
detection of	
determination of 344	^
electrolytic production of 589	${f Q}$
gravimetric factors 342	Onelitetine englants - 11
Potentials, anode	Qualitative analysis, acids 284
cathode	bases
Powdered fuel 557	Quicksilver, consumption sta-
Powellizing, description of 495	tistics
Power, algebraic formula 16	description of
concentrator 393, 394	detection of 274

Quickailver, prices, average 55	Ridgeway niter 392
production statistics 57, 58	Rigidity, coefficient of 194
$\mathbf{smelting}$	Ringelmann's smoke chart 438
_	Rittinger table 388
${f R}$	Roasting, copper-roasting fur-
	nace
Radian, value of 9	desulphatizing tempera-
Radiation, loss of heat by 453	tures 304
(See also Diffusivity and	efficiency of apparatus for, 524
Emissivity.)	factors for calculating prod-
Radioactive phenomena 245, 290	uct
Radioelements, chart showing	furnace dimensions 522
disintegration 247	heap roasting, time of 523
properties of	ignition and incandescence
Radium, detection of 275	temperatures 523
properties of	lead ores
recovery from Olary ores 595	loss with zinc ores 571
Randolph process, description	magnetism produced by 237
of	Montana roasting furnaces 516
Reaumur, temperature scale 3	Robson flotation patent 406
Recovery, calculation of mill. 418	Roll jaw crusher 357
Red metal, composition of 501	Rolls, crushing with 366, 368
Reduction, agents for, in assay-	width of 373
ing	Roller mill
	Rolling mill construction cost. 481
<u>- </u>	
by hydrogen 305	Rolling, steel, power consump-
temperatures of 305	tion
wet reagents 325	Roots, formulas for
Reese River process, description	Ropes, knot tying 469
of	curvature over pulleys 471
Refining capacity, copper, in	safe loads for
United States 74	Rose's metal, composition of 499
Refractories, description of com-	Rozan process, description of 495
mon	Rubidium, detection of 276
general subject 439-457	gravimatric factors 342
general subject 439-457	gravimetric factors 342 Russell process description of 495
general subject 439-457 heat conductivity 455-457	Russell process, description of 495
general subject 439-457 heat conductivity 455-457 melting points of firebrick. 447	Russell process, description of 495 Rust removal
general subject 439-457 heat conductivity 455-457 melting points of firebrick. 447 of oxides 446	Russell process, description of 495 Rust removal
general subject 439-457 heat conductivity 455-457 melting points of firebrick. 447 of oxides 446 permeability 455	Russell process, description of 495 Rust removal
general subject	Russell process, description of 495 Rust removal
general subject	Russell process, description of 495 Rust removal
general subject	Russell process, description of 495 Rust removal
general subject	Russell process, description of 495 Rust removal
general subject	Russell process, description of 495 Rust removal
general subject	Russell process, description of 495 Rust removal
general subject	Russell process, description of 495 Rust removal
general subject	Russell process, description of 495 Rust removal 317 Ruthenium, description of 266 detection of 276 S Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233
general subject	Russell process, description of
general subject	Russell process, description of. 495 Rust removal 317 Ruthenium, description of 266 detection of 276 S Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233 molecular weights of 216-233 solubility of, 205-207, 216-233
general subject	Russell process, description of. 495 Rust removal 317 Ruthenium, description of 266 detection of 276 S Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233 molecular weights of 216-233 solubility of, 205-207, 216-233 specific gravities 216-233
general subject	Russell process, description of 495 Rust removal
general subject	Russell process, description of. 495 Rust removal 317 Ruthenium, description of 266 detection of 276 S Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233 molecular weights of 216-233 solubility of 205-207, 216-233 specific gravities 216-233 Sampling of coal 332 of ores 330-331
general subject	Russell process, description of. 495 Rust removal 317 Ruthenium, description of 266 detection of 276 S Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233 molecular weights of 216-233 solubility of, 205-207, 216-233 specific gravities 216-233 Sampling of coal 332 of ores 330-331 Sanders flotation process 408
general subject	Russell process, description of 495 Rust removal 317 Ruthenium, description of 266 detection of 276 S Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233 molecular weights of 216-233 solubility of, 205-207, 216-233 specific gravities 216-233 Sampling of coal 332 of ores 330-331 Sanders flotation process 408 Scalds, treatment of 634
general subject	Russell process, description of 495 Rust removal 317 Ruthenium, description of 266 detection of 276 S Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233 molecular weights of 216-233 solubility of 205-207, 216-233 specific gravities 216-233 specific gravities 216-233 Sampling of coal 332 of ores 330-331 Sanders flotation process 408 Scalds, treatment of 634 Scandium, detection of 276
general subject	Russell process, description of 495 Rust removal 317 Ruthenium, description of 266 detection of 276 S Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233 molecular weights of 216-233 solubility of 205-207, 216-233 specific gravities 216-233 specific gravities 216-233 Sampling of coal 332 of ores 330-331 Sanders flotation process 408 Scalds, treatment of 634 Scandium, detection of 276 Screen analysis of ores 611
general subject	Rust removal 317 Ruthenium, description of 266 detection of 276 S Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233 molecular weights of 216-233 solubility of 205-207, 216-233 specific gravities 216-233 Sampling of coal 32 of ores 330-331 Sanders flotation process 408 Scalds, treatment of 634 Scandium, detection of 276 Screen analysis of ores 383-385
general subject	Rust removal 317 Ruthenium, description of 266 detection of 276 S Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233 molecular weights of 216-233 solubility of 205-207, 216-233 specific gravities 216-233 Sampling of coal 332 of ores 330-331 Sanders flotation process 408 Scalds, treatment of 634 Scandium, detection of 276 Screen analysis of ores 383-385 Second's pendulum, length of 10
general subject	Rust removal 317 Ruthenium, description of 266 detection of 276 Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233 molecular weights of 216-233 solubility of, 205-207, 216-233 specific gravities 216-233 specific gravities 216-233 Sampling of coal 332 of ores 330-331 Sanders flotation process 408 Scalds, treatment of 634 Scandium, detection of 276 Screen analysis of ores 383-385 Second's pendulum, length of 10 Seger cone data 450
general subject	Rust removal 317 Ruthenium, description of 266 detection of 276 S Safe loads for ropes and chains, 467 Salts, boiling points 216-233 formulas 216-233 melting points 216-233 molecular weights of 216-233 solubility of, 205-207, 216-233 specific gravities 216-233 Sampling of coal 332 of ores 330-331 Sanders flotation process 408 Scalds, treatment of 634 Scandium, detection of 276 Screen analysis of ores 318-385 Second's pendulum, length of 10 Seger cone data 450 Selenides, heat of formation 295
general subject	Rust removal
general subject	Rust removal
general subject	Rust removal
general subject	Rust removal
general subject.	Rust removal
general subject	Rust removal

Shakado, analysis of	Smelting, in blast furnaces, cop-
Sheet metal gages 512, 513	per
Shell steel, properties 506-508	in electric furnace, copper, 560
Sherardising, definition 495	sinc
Sherman settler	general notes on 525 et seq.
Shibuichi, analysis of 506	lead furnace 568
Shock, electric, first aid in 635 Shrinkage of castings 610	mercury 577
	nickel
of metals on solidifying 238 Siemens and Halske process, de-	in reverberatories 553
scription of 495	tin
Siemens-Martin process, de-	Smelting capacity, U.S., copper 72
scription of 496	lead 62
Silica, as a refractory 445, 448	silver-lead
Silicates, heat of formation of	sinc
292, 543	Smith process, description of 492
specific heats of 207	Smoke chart 438
total heat of fusion 211	Soddy's law for radioelements,
Silicides, composition of metal-	242, 248
lic	Sodium chloride, specific grav-
heat of formation 297	ity of solutions 127
Silicon bronze, composition of 501	Sodium, detection of 276
Silicon, determination of 353	determination of 344
gravimetric factors 342	gravimetric factors 342
Silicon irons	properties of 267
Sills, size of cross sills 381 size of mud sills 381	Softening, typical analyses 566
Siloxicon, a refractory 445	Solder, composition of 501 Soldering, fluxes for 511
Silver, alloys of	Solubility of air in water 215
chloride, solubility table. 589	of gases in water 215
description of 266	of salts in water,
detection of	211–213, 216–233
determination of 351	Solutions, densities of saline, 128-131
with platinum 281	heats of
electrolytic refining of 589	heats of
electroplating bath 312	specific gravity of saline,
gravimetric factors 342	128–131
ingot-mould sizes 607	standard
precipitation of, in cyanide	Solvay process, description of, 496
process	Sorbite, definition of 261
production statistics of,	Sound, velocity of
57, 65, 66	Sparking distance, electrical,
proof silver, production of, 322 Sines, table of	Specific gravity, alkaline solu-
Sinking funds, formulas for 18, 19	tions 127
tables	ammonia 126
Slaggability ratios, copper refin-	Baumé 113
ing	cyanide solutions 420
Slags, alumina in 528	fuel oils 430
Balling's tables 541	gangues 181
blende in 528	gases
degree of	hydrochloric acid 122
factors for	hydrofluosilicie acid 127
fluorspar in	liquids 171
general considerations 525	mercury 176
heats of formation 525-543 iron in 525	minerals 178–181
iron in	nitric acid
lime in	ores
losses in copper 558	salts
magnesia in	solids
manganese in	sulphuric acid 114
miscellaneous analyses 544	temperature correction 119
pyritic	units of 171
specific gravity of 533	water, various tempera-
sinc in 528	tures 175, 176
Slime, analyses of copper 583	Specific heat, of alloys 201
coagulants	definition of 4
flue dust (copper) 583	of elements
Smalt, production of 576	of gases 209, 210

Specific neat, of metals 201, 203	Sulphur trioxide, generation of, 18
non-metals	Sulphuric acid, density of 11
Spellerizing, definition of 496	manufacture of
Spelter, see "Zinc."	cost of plant
Spigots, flow of sand through 419	temperature correction. 11
Spitzlutte 388	Surface tension, of metals 14
Sprains, treatment of 632	Susceptibility, magnetic 234, 23
Square measure, tables of 6	Susceptivity
Square roots, table of 32	Sutton, Steele & Steele table 389
Squares, table of	Swing-hammer crusher 357, 358
Stainless steel 506	Symbols, chemical 254
Stamp mill, cost of 481	mathematical
Stamps, description of 357	Symons crusher 358
drops of 378	erushing with 364
mortar block data 382	_
mud sills, size of 381	${f T}$
power required 379	
sequence of drops 378	Tables, concentrating 385-389
steam 383	Tangents, tables of
Standard annealed copper 165	Tank capacity
Standard-solution strengths 318	Tantiron, composition of 499, 500
Starting-sheet electrolyte com-	for insoluble anodes 584
position 581	Tantulum, properties of 267
Steam, effect on molten lead 565	Tees, standards for 461–466
equivalent evaporation from and at 212° 134	Tellurides, heat of formation 295
	Tellurium, gravimetric factors, 343 properties of 267
properties of 140, 141 Steel, see also "Iron."	Temper carbon
electric furnaces for 619	tion for 110
Monell process 613	by color of iron
rolling, power consumption 617	combustion temperatures, 432
tempering	critical, of gases 183
Stein table	desulphatization 304, 571
Stellite, composition of 497, 506	distillation, zinc 572
Sterline, composition of 501	formation of slags.
Sterro's metal, composition of. 501	formation of slags, 525, 533-537, 543
Stone, voids in crushed 364	kindling 435
Strengths of materials 488, 490	melting points
Strontium, detection of 276	of metallurgical operations, 549
electrolytic production 590	scales of
gravimetric factors 342	steel tempering 614
properties of	Tempering, temperatures for 614
Sturtevant grinder 357	Tenacity of metals
ring roll crusher 358	Tensile strength of metals, 194, 195
roll jaw crusher 358	Thallium, detection of 276
rolls	gravimetric factors 343
Sulphates, dehydration tem-	Thermochemical constants, 291–307
peratures 302	Thermochemistry of blast-fur-
desulphatization tempera- tures	nace
tures	171, 308
heat of formation of 299	Thermometer, centigrade 3
specific heats of 204	Fahrenheit
Sulphides, decomposition tem-	Reaumur3
peratures 306	wet-bulb
heat of formation 296	Thermometry, color scales4, 453
of fusion 201	Erhard and Schertel fusion
oxidizing, with nater 325	mixtures 452
specific heats of 206, 207	metallic salts for 452
Sulphites, heats of formation. 301	Seger cones 450
Sulphur, affinity for various	standard melting points 4
metals 532	scales defined 3
detection of 276	Thiessen washer, work of 617
determination of 352	Thiogen process 600
gravimetrio factors 343	Thomas-Gilchrist process, defi-
Sulphur dioxide, generation of. 187	nition of
solubility in water 215	Thomson's rule for decomposi-
Sulphur-sand cement 607	tion e.m.f 309

Thorium, detection of 276	. V
gravimetric factors 343 properties of 291	Valence
Thum-Balbach process, definition of 496	Vanadium, detection of 277 gravimetric factors 343
Time, units of	Properties of
consumption of 70, 71	general data on 398-400
determination of 352	Vapor tension, arsenious acid 144 water 106, 110
electrolytic recovery 590 electroplating bath 312	Velocity of light
gravimetric factors 343	Vibracone
impurities in	Victor metal, composition of 501 Viscosity of sand-water mix-
production statistics 70 properties of 267	tures
smelting 574	Voltage of decomposition 315, 316
Tinfos furnace	Volume, formulas for 26, 27 measures of 8, 9
Titanium, detection of 277 determination of 347	W
gravimetric factors 343	
Tobin bronze, composition of 501 Tombac, composition of 501	Wall plates, allowable pressure on 480
Toughness of metals 193	Watchmaker's alloy, composi-
Toxic gases	tion
wire table 167 Kelvins rule 167	density of
Trent agitator 392	pipe and pump formulas 472
Triangle, solution of	pressure at various heads 473 pumping by compressed air
definitions	476, 480
numerical values of func-	required for concentrators, 395-397, 402
tions	solubility of salts in 210-233 specific heats of 208
tangent tables	speed necessary to move
Trommel 393	wave length of light 13
Troostite, definition of 261 Trough washer	Weight, atomic
Tube mill, description 355, 357	-pressure tables 13
grinding in 372, 373 Tungsten, detection of 268, 277	tables of
gravimetric factors 343 properties of 268	Weldon's process, description of 496 Wet measure
Turbadium bronze, composition	Wetherill magnetic concentra-
of	tor
tion of	Wilfley slimer
Type metal, composition of 501	Williams hinged-hammer
	wire bar analyses 583
U .	Wire, fusing currents 168
_	resistances of 167, 168
Ulcoloy, analysis of 506	Wohlwill process, description of 496 Wolf flotation patent 407
Ultrich magnetic separator 388 Ultimate strengths of materials,	Wood's metal, composition 501
489, 501	Wood preservatives, effective- ness of
Unstable alloys	Woodbury jig
electrolytic production 590	Work, equivalents in various
properties of 268, 290	units
recovery from Olary ores 595	Wounds, treatment of, 632